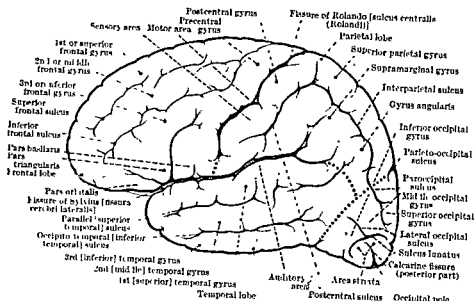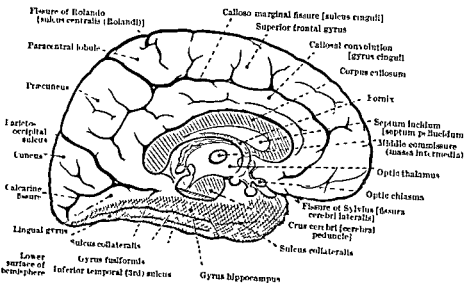# DISEASES OF THE
NERVOUS SYSTEM

LEFT CEREBRAL HEMISPHERE—EXTERNAL (LATERAL) ASPECT

LEFT CEREBRAL HEMISPHERE—INTERNAL (MEDIAL) ASPECT
(Pauchet and Dupret *Pocket Atlas of Anatomy*)

DISEASES OF THE

NERVOUS SYSTEM

BY

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PREFACE TO THE SECOND EDITION

THE important additions to knowledge which have been made in many fields of neurology since the first edition of this book was published have necessitated an extensive revision. Its general plan, however, remains the same. The enormous development of medical psychology makes it impossible to consider in detail the aetiology and treatment of the neuroses in a text-book of neurology. In dealing with the neuroses, therefore, I have considered them mainly in relation to neurological diagnosis. I have added a new chapter on 'The Psychological Manifestations of Organic Nervous Disease'. Although the treatment of this important subject is necessarily condensed I hope that this chapter will prove useful to students, since the subject is usually omitted from neurological text-books and receives only indirect consideration in text-books of psychiatry. Diseases attributed to neurotropic viruses are now grouped together, as also are those which have come to be known as the demyelinating diseases

Recent advances which receive discussion include electro-encephalography, the role of vitamin deficiency in nervous disease, newly discovered neurotropic viruses, and the progress which has been made in our knowledge of the chemistry of muscle and of humoral factors in the transmission of nerve impulses at the myoneural junction. I have also added sections on a number of new topics in order to make the book more complete. To make room for new material without unduly enlarging the book I have omitted sections dealing with endocrine and trophic disorders which are not strictly neurological.

A number of new illustrations have been included. Pathological illustrations of the commoner nervous diseases have kindly been provided by Dr. Dorothy S. Russell and most of the X-ray illustrations by Dr Montagu Jupe. To them and to the many friendly critics, both at home and abroad, who have offered helpful suggestions, I am most grateful.

March, 1940   W. RUSSELL BRAIN

PREFACE TO THE FIRST EDITION

THE last twenty years have witnessed a remarkable development in neurology. Investigation of the effects of war injuries of the spinal cord has greatly increased our knowledge of reflex action in man. The appearance of encephalitis lethargica and the multiplication of forms of acute disseminated encephalitis have added a new field to clinical neurology and brought it into relationship with the new branch of bacteriology which studies the filterable viruses. The discovery of important metabolic centres in the hypothalamus has enhanced the importance of neurology to general medicine. Advances in the technique of neurological surgery have aroused fresh interest in the symptoms and in the pathology of intracranial tumours. Other developments, scarcely less important, have occurred.

Much of this new knowledge is physiological, and in one respect I have departed from the traditional arrangement of a text-book of nervous diseases. Neurology is more dependent than many other branches of medicine upon anatomy and physiology. These subjects, the essential basis of neurological diagnosis, are usually dismissed in a few introductory pages, with the result that much clinical neurology is apt to be both unintelligible and uninteresting to the student. In the first part of this book, as an introduction to the subject, I have discussed—at greater length than usual—the application of anatomy and physiology to the interpretation of the physical signs of nervous disease. Elsewhere will be found sections dealing with anatomy and physiology as introductions to clinical sections. In planning the clinical sections I have used what seemed the most practical, if not always the most logical, arrangement, for there is no entirely satisfactory way of arranging subjects, many of which might be placed in more than one group.

Limitations of space restrict the number of references which it is possible to quote. I have, therefore, chosen only those of special interest and those which form the best introduction to a subject, or are themselves useful sources of references. To the many other writers upon whose work I have freely drawn I express my indebtedness. I am indebted also to a number of my colleagues for the loan of illustrations.

Finally, I welcome this opportunity of expressing my gratitude to my colleagues at the London Hospital for their teaching,

encouragement, and help, especially to Dr. Charles Miller, Professor Arthur Ellis, and Dr. George Riddoch, under whom I had the privilege of working on the Medical Unit, and to Mr. Hugh Cairns, Dr. Dorothy Russell, and Dr. S. Phillips Bedson.

W. RUSSELL BRAIN

LONDON
June, 1933

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CHAPTER I

DISORDERS OF FUNCTION IN THE LIGHT OF ANATOMY AND PHYSIOLOGY

I. THE PYRAMIDAL TRACT

ANATOMY

(1) The Precentral Convolution.

THE pyramidal tract is the means by which the nervous impulses which excite voluntary movements pass from the cerebral cortex to the lower motor neurones which arise in the brain-stem and spinal cord. The pyramidal fibres or upper motor neurones are the axones of the large pyramidal or Betz cells of the precentral convolution. Electrical excitation of these cells causes movements of the opposite side of the body. The movements thus excited are not simply contractions of isolated muscles, but always involve groups of muscles contracting harmoniously, so that an orderly movement results. The upper motor neurones therefore are organized in terms of movements, in contrast to the lower motor neurones, which are distributed to groups of muscle-fibres in individual muscles.

Since the electrical excitation of different parts of the precentral convolution evokes movements of different parts of the opposite side of the body, we are justified in speaking of the representation of parts of the body in this part of the brain. According to Foerster's observations the order in which the parts of the body are thus represented is as follows (Fig. 1):

At the lowest part of the precentral convolution the centres for movements of the larynx and pharynx are situated. Unilateral stimulation of the cortex causes bilateral contraction of the pharynx and adduction of both vocal cords. Next above lie the centres for the palate, mandible, and tongue in that order. Palatal movements are bilateral; the mandible and tongue are deviated to the opposite side. Above the tongue centre come the centres for the lower and upper face. Movements of the lower face excited from the cortex are unilateral, those of the upper face bilateral. Movements of the neck muscles are elicited from the region next above, the ipsilateral *sternomastoid* contracting to produce rotation of the head to the opposite side. Above this are the foci for the thumb and fingers, that for the thumb being the lowest and that for the little finger the highest. Above these are the centres for the wrist, forearm, arm, and shoulder, and the upper and lower regions of the trunk. A centre for the diaphragm lies in front of that for the upper part of the trunk. Stimulation of the trunk centres readily induces bilateral movements.

B

fingers is less marked The lower limb is extended, with plantar flexion and often slight inversion of the foot. The extensor attitude of the lower limb maintained by hypertonia of the extensor muscles may be regarded biologically as the posture of reflex standing, a condition akin to the extensor rigidity of the decerebrate animal

3. *Reflexes.* After a lesion of the pyramidal tract the tendon reflexes on the paralysed side become exaggerated when shock has passed off, and clonus may be present in the flexors of the fingers, the quadriceps femoris, and the calf muscles. The abdominal and cremasteric reflexes are diminished or lost and the plantar reflex becomes extensor. These reflex changes are more fully described on p 37. Wasting does not occur in the muscles as a result of a lesion of the pyramidal tract

THE LOCALIZATION OF LESIONS OF THE PYRAMIDAL TRACT

The characteristics of hemiplegia resulting from a lesion of the pyramidal fibres in the internal capsule have been described. The following are the distinctive symptoms of lesions of the pyramidal tract elsewhere in its course

(1) Cortical Lesions.

The chief characteristic of cortical pyramidal lesions arises out of the wide surface-distribution of the tract in this region. As a result of this a lesion of moderate size involves only a part of the fibres. In contrast to the conditions obtaining in the internal capsule, where the fibres are so crowded that even a small lesion usually produces a complete hemiplegia, cortical pyramidal lesions usually produce a monoplegia, that is, paralysis of the face or of one limb only, without, or with only slight, implication of adjoining cortical areas.

Jacksonian Convulsions. Since the precentral cortex contains the bodies of the pyramidal cells, a cortical lesion in this region may lead to excitation of the pyramidal fibres, which expresses itself as a convulsion This is of the well-recognized type described by Hughlings Jackson and hence known as Jacksonian Such a convulsion begins as a rule with clonic movements, rarely with tonic spasm, of a small part of the opposite side of the body corresponding to the region of the cortex excited, and gradually spreads to adjacent parts, the extension following their anatomical representation in the precentral gyrus, those parts being involved next after the onset which are represented in the cortex immediately adjacent to the original site of excitation Jacksonian convulsions are more fully described on p. 247.

or playing the piano, may be more evident than actual weakness. Moreover, after a pyramidal lesion movements are not confined to the appropriate parts, but the limbs tend to move as a whole. Finally, probably owing to the distribution of the muscular hypertonia, movements of flexion tend to be stronger than those of extension in the upper limb, while the reverse is the case in the lower limb.

6. *Respiratory Movements* As Hughlings Jackson first demonstrated, during quiet breathing the amplitude of the thoracic expansion tends to be greater on the paralysed than on the normal side, but during vigorous voluntary breathing the opposite occurs.

7. *Gait.* The hemiplegic patient in walking circumducts his paralysed leg, swinging it outwards at the hip to obviate the difficulty arising from inability to flex it at the knee. The foot is plantar flexed, hence the toe tends to drag and the sole of his shoe thus becomes worn at the toe.

Positive Symptoms.

1. *Muscular Hypertonia* Immediately following a capsular haemorrhage the paralysed limbs are completely flaccid owing to the occurrence of neural shock. After a variable interval, usually two or three weeks, tone gradually returns to the affected muscles and they ultimately become hypertonic or 'spastic'. This is a state of continuous contraction which manifests itself to the eye in their increased salience, and to the touch in an added tension of the muscles on palpation and in the increased resistance which they offer to passive movements at the joints Not all muscle-groups exhibit hypertonia in equal degree in hemiplegia. In the upper limb the adductors and internal rotators of the shoulder, flexors of the elbow, wrist and fingers, and the pronators of the forearm are usually more spastic than their antagonists Very rarely the increase of tone is more marked in the extensors of the elbow than in the flexors. In the lower limb the hypertonia predominates in the adductors of the hip, the extensors of the hip and knee, and in the plantar flexors of the foot and toes. In time contractures tend to develop in the spastic muscles.

2. *Posture* The hemiplegic posture is the outcome of the selective distribution of hypertonia in the limb muscles, the more spastic muscles determining the position of the limb segments. Hence we find the upper limb usually adducted and internally rotated at the shoulder, flexed to a right angle at the elbow, somewhat pronated, and flexed at the wrist and fingers In the exceptional cases in which hypertonia predominates in the extensors of the upper limb its attitude is one of extension at the elbow, and flexion of the wrist and

fingers is less marked. The lower limb is extended, with plantar flexion and often slight inversion of the foot. The extensor attitude of the lower limb maintained by hypertonia of the extensor muscles may be regarded biologically as the posture of reflex standing, a condition akin to the extensor rigidity of the decerebrate animal.

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(2) Subcortical Lesions.

In the corona radiata the pyramidal fibres are converging towards the internal capsule and are closer together than in the cortex. Subcortical lesions tend therefore to involve more fibres than cortical lesions of equal size, and it is usual to find that, though the weakness predominates in one limb, the whole of the opposite side of the body is to some extent affected. Adjacent thalamo-cortical sensory fibres may also be involved, causing impairment of postural sensibility and tactile discrimination and localization in the affected limbs. Damage to the optic radiation causes crossed homonymous hemianopia.

(3) Lesions in the Midbrain.

Here the proximity of the pyramidal fibres to the third nerve sometimes adds signs of localizing value. Thus we may encounter paralysis of the third nerve with hemiplegia on the opposite side (*Weber's syndrome*). Throughout the brain-stem the two pyramidal tracts lie close together. Vascular lesions are often strictly unilateral, but space-occupying lesions, such as tumours, frequently involve both pyramidal tracts. The pyramidal fibres decussate at different levels, those destined for the opposite facial nucleus, for example, crossing at the junction of the midbrain and the pons, while those which are concerned in the movements of the limbs do not cross till they reach the pyramidal decussation in the medulla. A lesion in the middle line situated anteriorly at the junction of the midbrain and pons may thus involve only the decussating fibres running to the facial nuclei, and so produce facial diplegia of the supranuclear type. This may be associated with bilateral paralysis of lateral conjugate ocular deviation, the supranuclear fibres for this movement crossing the middle line at the same level.

(4) Lesions in the Pons.

Owing to the higher level of decussation of the cortico-facial pyramidal fibres a unilateral pyramidal lesion in the pons does not cause weakness of the opposite side of the face, but only of the opposite bulbar muscles and limbs. The lesion may, however, also involve the facial nucleus or the intrapontine fibres of the facial nerve on the same side, thus causing one form of 'crossed hemiplegia'. Many forms of this have been described and named after their earliest observers.

Millard-Gubler's Syndrome consists of paralysis of the external rectus, with or without facial paralysis of the lower motor neurone type on one side and supranuclear paralysis of the bulbar muscles and limbs on the opposite side.

Foville's Syndrome is similar to Millard-Gubler's syndrome, except that paralysis of conjugate ocular deviation to the side of the lesion takes the place of external rectus paralysis.

Ipsilateral paralysis of the jaw muscles may be associated with either of these syndromes. When the lesion is situated deeply in the pons, near the middle line, involvement of the median fillet causes impairment of postural sensibility on the opposite side of the body. When the lesion is mainly in the lateral region of the pons the fillet escapes but damage to the spino-thalamic tract causes crossed analgesia and thermo-anaesthesia, with or without some impairment of sensibility in the trigeminal area on the side of the lesion, owing to involvement of the trigeminal fibres within the pons.

Horner's Syndrome, paralysis of the ocular sympathetic, may also result from a lesion in the tegmentum of the pons.

(5) Lesions in the Medulla.

Many varieties of crossed hemiplegia have been described as a result of unilateral medullary lesions. A lesion near the middle line will involve the pyramidal fibres to the limbs above their decussation, together with the fibres of the hypoglossal nerve, causing unilateral paralysis of half of the tongue, with crossed hemiplegia of the limbs, to which loss of postural sensibility in the paralysed limbs may be added. When the lateral region of the medulla is affected as well there will also be paralysis of the soft palate and vocal cord, with Horner's syndrome and trigeminal analgesia and thermo-anaesthesia and some cerebellar deficiency, all on the side of the lesion, with loss of appreciation of pain, heat, and cold in the limbs and trunk on the opposite side. Vascular lesions in the middle line of the medulla may involve both pyramidal tracts, leading to quadriplegia with unilateral paralysis of the tongue.

(6) Spinal Hemiplegia.

A unilateral lesion of the pyramidal tract in the spinal cord below the medulla and above the fifth cervical segment causes hemiplegia involving the limbs on the affected side but without paralysis of the muscles innervated by the cranial nerves.

DECEREBRATE MAN

A condition which appears to be physiologically homologous with decerebration in the animal may occur in man, either in the form of a convulsion or as a prolonged state of muscular hypertonia without loss of consciousness. The convulsions—'tonic' fits, or 'cerebellar' fits of Hughlings Jackson—are characterized by opisthotonos and

rigid extension of all four limbs. The upper limbs are internally rotated at the shoulder, extended at the elbow and hyperpronated, and the fingers are extended at the metacarpo-phalangeal joints and flexed at the interphalangeal joints. The lower limbs are extended at the hip and knee, and the ankles and toes are plantar-flexed This human decerebrate attitude has been observed to result from lesions at the level of the upper part of the midbrain, such as tumours arising in the midbrain, and pineal tumours and tumours of the cerebellar vermis, which compress the midbrain from without. It may also be produced by diffuse cerebral disturbances, such as hydrocephalus and diffuse sclerosis, which grossly damage the functions of both cerebral hemispheres. It is probably the result of interruption of both pyramidal and rubrospinal tracts.

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2. THE LOWER MOTOR NEURONE

The cell bodies of the lower motor neurones are situated in the motor nuclei of the brain-stem and the anterior horns of the grey matter of the spinal cord. Their dendrites receive impulses from the axones of the pyramidal tracts, either directly, or through intercalated neurones, and also from those nerve-fibres which act as conductors in the reflex arcs Their axones pass into the cranial and spinal nerves, reaching the latter by way of the anterior roots, the motor functions of which were first recognized by Bell in 1811. From the spinal nerves they are distributed to the peripheral nerves, those destined for the limbs passing *en route* through the cervical, lumbar, and sacral plexuses. Each lower motor neurone terminates in relation with a bundle of 150 or more muscle-fibres Injury to the lower motor neurone leads to characteristic symptoms.

SYMPTOMS OF LESIONS OF THE LOWER MOTOR NEURONE

(1) Muscular Weakness.

Weakness or complete paralysis occurs in the affected muscles, according to the severity of the lesion. This is an impairment of the function of the muscle itself, and therefore is manifest equally in all movements in which the affected muscle normally plays a part.

(2) Muscular Wasting occurs in the affected muscles This is conspicuous within two or three weeks of an acute lesion, such as acute poliomyelitis or division of a motor nerve, but develops very gradually in chronic disorders such as amyotrophic lateral sclerosis

(3) Distribution.

The distribution of the weakness and wasting is the outcome of the grouping of the lower motor neurones at the point at which the damage occurs (see pp. 17-22).

(4) Hypotonia.

Since muscle tone is a state of sustained contraction resulting from impulses reaching the muscles by the lower motor neurones, a lesion of this path causes hypotonia, which is manifested in flaccidity and a diminished resistance to stretching of the affected muscles.

(5) Reflexes.

The reflexes in which the affected muscles take part are diminished or lost through interruption of their motor paths An apparent exception to the rule that hypotonia and loss of reflexes result from lower motor neurone lesions is found when the same patient has also a lesion of the upper motor neurone, as in amyotrophic lateral sclerosis. In such cases the hypertonia and increased tendon reflexes produced by the upper motor neurone lesion may more than counterbalance the opposite effects of the lower motor neurone lesion Such patients may show increased tendon reflexes in the wasted muscles—so-called 'tonic muscular atrophy'.

(6) Muscular Fasciculation and Fibrillation.

Fascicular twitching of muscles is seen in its most typical form as a result of chronic degeneration of the anterior horn cells in progressive muscular atrophy. In such cases each twitch involves a group of muscle fibres. It does not occur when these cells are rapidly injured or destroyed as in acute anterior poliomyelitis, and it is very rare when they suffer from compression as in syringomyelia or spinal tumour. It is occasionally seen in acute inflammatory lesions of the

peripheral nerves, for example when the facial nerve is involved in zoster of the geniculate ganglion, and, rarely, in sciatic neuritis, but is absent in polyneuritis and the muscular dystrophies. Fascicular twitching of the facial muscles, especially the orbicularis oculi, is common as a transitory occurrence in normal persons—'live blood', or myokymia—and is also found in clonic facial spasm, a progressive disorder of unexplained origin. Spasmodic facial contractions are also seen during recovery from facial paralysis. A few isolated muscular twitchings are often seen in bedridden patients, especially in the calves. Finally, completely denervated muscle shows a fine flickering fibrillation only visible with difficulty (Denny-Brown and Pennybacker, 1938).

(7) Muscular Contractures.

Muscular contracture, leading to permanent shortening, may occur in muscles of which the lower motor neurones are damaged, for example in the facial muscles after Bell's paralysis. More often it develops in their antagonists, the action of which is no longer opposed by the paralysed muscles. An example of this is contracture of the calf muscles following paralysis of the anterior tibial group and the peronei in acute anterior poliomyelitis. Appropriate splinting, passive movements, and massage are required to prevent such contractures

(8) Trophic Changes.

Lesions of the lower motor neurones are often attended by so-called trophic changes. The affected extremity is cold and cyanosed, the finger- and toe-nails are brittle, and the bones are smaller and lighter than normal. These changes are probably due partly to disuse, with loss of the influence of muscular action upon the circulation and the development of the bones, and partly to vasomotor paralysis from destruction of the vasoconstrictor fibres of the sympathetic.

(9) Reaction of Degeneration.

Normal muscles respond vigorously to stimulation by the faradic (interrupted) and galvanic (constant) currents. Faradism causes a muscular contraction which persists as long as the current is passing. Galvanism causes a contraction only when the current is made or broken, but not while it is passing. A smaller current is required to excite the muscle when the kathode is used as a stimulus and the current is closed (K.C.C. = kathodal closing current) than when the anode is similarly used (A.C.C. = anodal closing current). After a lesion of the lower motor neurone a muscle ceases to respond to

faradic stimulation of its motor point in from four to seven days. After ten days a normal response to galvanism ceases to be obtainable, but the muscle responds to this form of stimulus by a sluggish, wave-like contraction starting at the point stimulated and requiring a stronger current for its elicitation than the normal muscle. Moreover, the anodal closing current is now a more effective stimulus than the kathodal (A.C.C.>K.C.C.), a phenomenon known as polar reversal. These changes, of which the last is the least important, are known collectively as 'the reaction of degeneration'.

These electrical tests are of special value in determining the degree of injury to the lower motor neurones, and hence are of importance in prognosis. Thus the persistence of a response to faradism in a muscle three weeks after a lesion of the nerve indicates that the lesion is incomplete, and the loss of all response to galvanism means that recovery is no longer possible. For an account of the situation of the motor points and the technique of electrical testing, readers are referred to text-books on medical electricity.

SEGMENTATION IN THE SPINAL CORD

It will be remembered that early in foetal development the body shows a division into a series of segments or metameres. This primitive segmentation to a large extent determines the subsequent plan of the lower motor and first sensory neurones at their emergence from, and entrance into, the spinal cord. Corresponding to each spinal segment is one pair of spinal nerves composed of the anterior and posterior roots of that segment. The cell bodies of the first sensory neurone, which lie in the posterior root ganglia, are completely separated in each segment from those of the segments above and below. The cell bodies of the lower motor neurones, however, lie in longitudinal columns in the anterior horns, hence their segmental grouping is less distinct. Nevertheless, the emergence of their axones by a series of separate anterior roots is the basis of a motor segmental arrangement, for we may regard as a segment of the cord from the aspect of motility that group of anterior horn cells of which the axones emerge by one pair of anterior roots and join one pair of spinal nerves.

The Segmental Representation of Muscles

As we have seen, the cells of the anterior horns lie in longitudinal columns and those which innervate a single muscle commonly extend over more than one segment longitudinally. Further, a number of such longitudinal columns may be recognized cut transversely in a transverse section of the cord. Hence several muscles may

be represented in the same segment. It follows that complete destruction of the anterior horn cells in one segment, or of their axones in one anterior root or spinal nerve, causes weakness of all those muscles which are innervated from that segment, but completely paralyses only such as have no nerve-supply from adjacent segments

Through the cervical and lumbo-sacral plexuses the axones of the lower motor neurones are redistributed and enter into new groupings in the peripheral nerves Consequently the fibres from a single spinal segment may reach several peripheral nerves, and conversely a single peripheral nerve may receive fibres from several spinal segments Thus we can distinguish between a lesion of a spinal segment, anterior root, or spinal nerve, on the one hand, and a lesion of a peripheral nerve on the other, because the resulting muscular weakness has a distinctive anatomical distribution. For example, the fifth cervical spinal segment innervates the supraspinatus and infraspinatus, deltoid, biceps, brachialis anticus and supinator longus, muscles which receive their peripheral nerve-supply from the suprascapular, circumflex, musculo-cutaneous, and musculo-spiral nerves respectively. These muscles cannot be paralysed by a lesion involving any single peripheral nerve, nor could a peripheral nerve lesion affect them without affecting others. Such a distribution of muscular weakness indicates a segmental lesion

On the other hand, if the supinator longus is paralysed in association with the triceps and the extensors of the wrist and fingers, this grouping points to a lesion of the musculo-spiral nerve which supplies all these muscles.

SEGMENTAL INNERVATION OF MUSCLES OF UPPER EXTREMITY
(Bing)

		Cervical Segments			Dorsal Segments
	5	6	7	8	1
Shoulder	Supraspinat.				
	Teres min.				
	Deltoideus				
	Infraspinatus				
	Subscapularis				
		Teres major			
Arm	Biceps				
	Brachialis				
		Coracobrachialis			
			Triceps brach		
			Anconeus		
	Supinator long				
Forearm	Supinator brevis				
	Extensor carpi radial				
		Pronator teres			
		Flexor carpi radial			
		Flexor pollic long			
		Adduct poll long			
		Extens poll brev			
		Extens poll long			
		Extens digit comm.			
		Extens indicis prop			
		Extens carpi uln			
		Extens dig V prop			
			Flex digitor sublimis		
			Flex digitor profund		
			Pronator quadrat		
			Flex carpi uln		
			Palmaris long		
Hand		Abduct poll brev			
		Flex. poll. brev.			
		Opponens poll			
			Flexor digit. V		
			Opponens dig V.		
			Adduct. poll		
			Palmaris brev.		
			Abductor dig V.		
			Lumbricales		
			Interossei		

SEGMENTAL INNERVATION OF TRUNK MUSCLES (Ling)

SEGMENTAL INNERVATION OF MUSCLES OF LOWER EXTREMITY

(Bing)

	D₁₂	L₁	L₂	L₃	L₄	L₅	S₁	S₂	S₃

Hip

- Ilio-psoas
- Tensor fasciae
- Gluteus medius
- Gluteus minim
- Quadratus femoris
- Gemellus inferior
- Gemellus super
- Gluteus maxim
- Obturator intern
- Piriformis

Thigh

- Sartorius
- Pectineus
- Adduct long
- Quadriceps
- Gracilis
- Adductor brevis
- Obturator ext
- Adduct magn
- Adduct minim
- Articularis gen
- Semitendinosus
- Semimembranosus
- Biceps femoris

Leg

- Tibialis ant
- Extensor halluc long
- Popliteus
- Plantaris
- Extensor digit long
- Soleus
- Gastrocnemius
- Peroneus longus
- Peroneus brevis
- Tibialis postic
- Flexor dig long
- Flexor halluc long

Foot

- Extensor halluc brev
- Extensor digit brevis
- Flex dig brev.
- Abduct hall
- Flex halluc brev.
- Lumbricales
- Abduct hall
- Abduct dig V.
- Flexor dig V. br.
- Opponens dig. V.
- Quadrat plant.
- Interossei

MUSCULAR SUPPLY OF PERIPHERAL NERVES

(modified from Bing)

A. PLEXUS CERVICALIS (C_1–C_4)

Nervi cervicales	Musculi profundi colli	Flexion, extension, and rotation of the neck
	Mm. scaleni	Elevation of ribs (inspiration)
N. phrenicus	Diaphragma	Inspiration

B. PLEXUS BRACHIALIS (C_5–D_1)

N. thoracic. ant.	M. pect. maj. et min.	Adduction and forward depression of the arm
N. thoracic long	M. serrat. ant.	Fixation of the scapula during elevation of the arm
N. dorsalis scap.	M. levator scapul.	Elevation of the scapula
	Mm. rhomboidei	Elevation and drawing inwards of the scapula
N. suprascap.	M. supraspinatus	Elevation and external rotation of the arm
	M. infraspinatus	External rotation of the arm
N. subscapul.	M. latissimus dors.	Internal rotation and dorsal adduction of the arm
	M. teres major	
	M. subscapularis	Internal rotation of the arm
N. axillaris s. circumflexus	M. deltoideus	Elevation of the arm to the horizontal
	M. teres minor	External rotation of the arm
N. musculocut.	M. biceps brach.	Flexion and supination of the forearm
	M. coraco-brachialis	Flexion and adduction of the forearm
	M. brachialis ant.	Flexion of the forearm
N. medianus	M. pronator teres	Pronation
	M. flexor carpi rad.	Flexion and radial flexion of the hand
	M palm. long.	Flexion of the hand
	M. flex. digit. sublim.	Flexion of the middle phalanges of the fingers
	M. flex. poll. long.	Flexion of the terminal phalanx of the thumb
	M. flex. digit. prof. (radial portion)	Flexion of the terminal phalanges of the index and middle fingers
	M. abduct. poll. brev.	Abduction of the first metacarpal
	M. flex. poll. brev.	Flexion of the first phalanx of the thumb
	M. opponens poll.	Opposition of the first metacarpal

N. ulnaris	M. flexor carpi uln.	Flexion and ulnar flexion of the hand
	M. flex. digit. prof. (ulnar portion)	Flexion of the terminal phalanges of the ring and little fingers
	M. adductor poll.	Adduction of the first metacarpal
	Mm. hypothenares	Abduction, opposition and flexion of the little finger
	Mm. lumbricales	Flexion of the first phalanges, extension of the others
	Mm. interossei	The same; in addition, abduction and adduction of the fingers
Nervus radialis	M. triceps brach.	Extension of the forearm
	M. supin. longus[1]	Flexion of the forearm
	M. extensor carpi rad.	Extension and radial flexion of the hand
	M. extensor digit. comm.	Extension of the first phalanges of the fingers
	M. extensor digit. V prop.	Extension of the first phalanx of the little finger
	M. extensor carpi uln.	Extension and ulnar flexion of the hand
	M. supinator brevis	Supination of the forearm
	M. abduct. poll. longus	Abduction of the first metacarpal
	M. extensor poll. brevis	Extension of the first phalanx of the thumb
	M. extensor poll. longus	Abduction of the first metacarpal and extension of the terminal phalanx of the thumb
	M. extensor indic. prop.	Extension of the first phalanx of the index finger

C. NERVI THORACALES

	Mm. thoracici et abdominales	Elevation of the ribs, expiration, compression of abdominal viscera, &c.

[1] The name 'supinator longus' is incorrect, inasmuch as electrical excitation experiments show that the muscle has no supinating, but, on the contrary, a slight pronating action For this reason a preferable name is that of 'brachioradialis'. This is in common use among anatomists, but has not yet been adopted by clinicians.

D. Plexus Lumbalis (D₁₂—L₄)		
N. cruralis	M. ilio-psoas	Flexion of the hip
	M. sartorius	Internal rotation of the leg
	M. quadriceps	Extension of the leg
N. obturatorius	M. pectineus	
	M. adductor longus	
	M. adductor brevis	Adduction of the thigh
	M. adductor magnus	
	M. gracilis	
	M. obturator extern.	Adduction and external rotation of the thigh
E. Plexus Sacralis (L₄—S₃)		
N. gluteus sup.	M. gluteus med.	Abduction and internal rotation of the thigh
	M. gluteus min.	
	M. tens. fasciae latae	Flexion of the thigh
	M. piriformis	External rotation of the thigh
N. gluteus inf.	M. gluteus max.	Extension of the thigh
N. ischiadicus	M. obturator int.	
	Mm. gemelli	External rotation of the thigh
	M. quadratus fem.	
	M. biceps femoris	
	M. semitendinosus	Flexion of the leg
	M. semimembranosus	
(a) N. peroneus.		
(a) Prof.	M. tibialis ant.	Dorsal flexion and inversion of the foot
	M. extens. digit. long.	Extension of the toes
	M. extens. hall. long.	Extension of the great toe
	M. extens. digit. brev.	Extension of the toes
	M. extens. hall. brev.	Extension of the great toe
(b) Superf.	Mm. peronei	Dorsal flexion and eversion of the foot
(β) N. tibialis	M. gastrocnemius	Plantar flexion of the foot
	M. soleus	
	M. tibialis post.	Plantar flexion and inversion of the foot
	M. flex. digit. long.	Flexion of the terminal phalanges, II–V
	M. flex. halluc. long.	Flexion of the terminal phalanx of the great toe
	M. flex. digit. brev.	Flexion of the middle phalanges, II–V
	M. flex. halluc. brev.	Flexion of the first phalanx of the great toe
	M. plant. reliqui	Movements of the toes
N. pudendus	Mm. perinei et sphinct.	Closure of sphincters, co-operation in sexual act

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3. SENSATION

THE EXAMINATION OF SENSATION

The neurologist is concerned with sensibility primarily for the
purpose of localizing lesions in the nervous system and determining
their nature. His methods of investigation are therefore more
'rough and ready' than those of the experimental psychologist, and
have been adopted on account of their practical value for his im-
mediate purpose.

Spontaneous Sensations.

The investigation should begin with a careful inquiry whether the
patient has experienced any abnormal spontaneous sensations or
paraesthesiae. The commonest such sensation is pain, but in addi-
tion parts of the body may be described as feeling hot, cold, numb,
dead, or heavy, and such abnormal feelings as constriction, itching,
tingling, 'pins and needles', and 'electric shocks' may be experienced.
When a patient complains of an abnormal sensation it is necessary
to ascertain its situation and duration, whether it irradiates and if
so in what direction, whether it is excited by movement or by any
external stimulus, and whether it is attended by hypersensitiveness
of the skin to painful or other stimuli.

'Root-pains' are pains due to a lesion of one or more spinal
posterior roots and are experienced in the segmental areas in-
nervated by the affected roots. They may be excited or intensified
by coughing or sneezing or changes of posture.

A patient with a lesion of the posterior columns of the spinal
cord in the cervical region may complain of a feeling like an electric
shock radiating through the body on flexing or extending the cervical
spine.

A strange sensory abnormality is the 'phantom limb'. A patient
who has lost a limb by amputation may continue to feel as if the
limb were still there, and may even experience pain in the phantom
limb. Similarly a patient who has lost all power of sensation in a
limb or limbs as a result of a lesion of the spinal cord or brain may
imagine that he feels his anaesthetic limb and that it occupies a
posture different from its real position.

Objective Sensory Tests.

Light Touch.

The appreciation of light touch is most conveniently investigated by means of a very small wisp of cotton-wool applied to the shaved skin, care being taken that no pressure is exerted upon the skin. The patient with his eyes closed is asked to reply each time he feels a touch

Pressure Touch.

Pressure touch is similarly investigated by pressing with a blunt object such as the unsharpened end of a pencil.

Localization of Touch.

The part of the body under investigation is screened from the patient's eyes and after he has been touched he is asked to name the spot or to point to it. For greater accuracy he may indicate it upon a diagram.

Superficial Pain.

Superficial pain is investigated by pricking the skin with a pin or needle It should be noted that this stimulus evokes a tactile sensation of sharpness as well as a feeling of pain. The patient's attention must therefore be directed to the painful element in the feeling In mapping out cutaneous areas of analgesia or hyperalgesia the point of a pin may be dragged along the skin, the patient being asked to say when the change to normal or exaggerated painful sensibility occurs

Pressure Pain.

Deep pressure, if sufficiently vigorous, normally excites pain. This is most simply tested by compressing a muscle between the fingers and thumb or by squeezing a tendon such as the tendo Achillis

Temperature

For testing appreciation of temperature, metal tubes, made of copper or silver, should be used, since glass is a relatively poor conductor of heat. For ordinary purposes one tube should be filled with ice and the other with water at a temperature of 45° C. The tubes are applied to the skin and the patient is asked to describe his sensations If the water is too hot confusion may arise, since a sensation of pain may be excited.

Postural Sensibility.

Postural sensibility, or sense of position, is tested by placing a segment of a limb in a certain position and asking the patient to describe its posture or imitate it with the opposite limb.

Passive Movement.

Power of appreciating passive movement is tested by passively moving a segment of a limb at a joint and finding the angle through which it has to be moved in order that the patient can appreciate the movement. The part to be moved should always be grasped in such a way that the observer's fingers are applied to surfaces parallel to the plane of movement to eliminate the perception of variations in their pressure. Slighter degrees of movement are appreciated at the joints of the fingers and toes than at the more proximal joints of the limbs. Normally a movement of a few degrees is recognized at the interphalangeal and metacarpo- and metatarso-phalangeal joints.

Vibration.

To test the appreciation of vibration, a tuning-fork C° beating 128 times a second is struck and applied to the part to be investigated. Normally the characteristic tingling sensation is readily felt. Normally also if the patient is asked to say when he ceases to feel the vibration and the fork is then transferred to the opposite limb it again becomes perceptible. When appreciation of vibration is impaired on one side of the body this second response is longer when the fork is transferred from the affected to the normal side than vice versa. After the age of 50 the appreciation of vibration may be reduced in normal persons.

Tactile Discrimination.

Tactile discrimination is measured by ascertaining the distance which two compass-points require to be separated in order that the patient may appreciate them as two and not one. Special compasses with blunt points are used, and these are furnished with a scale which indicates the distance the points are separated. The part to be tested is successively touched with two points and with one in a random order, and the number of correct answers and errors noted. The corresponding part on the opposite side, when normal, is used as a control, and to determine the normal threshold, that is, the distance of separation necessary for accurate discrimination. Normally 1 cm. of separation is appreciated on the palmar surface of the thumb and fingers.

Appreciation of Form.

Stereognosis, or the appreciation of form in, three dimensions, is tested by asking the patient with his eyes closed to recognize

common objects placed in his hand. If there is marked paralysis of the fingers the object must be moved about by the observer in the patient's hand

THE FIRST SENSORY NEURONE

The first sensory neurone is the path by which sensory impulses from the periphery reach the central nervous system. The cell bodies of the first sensory neurones are situated in the spinal posterior root ganglia and in the corresponding sensory ganglia of the cranial nerves. They are bipolar cells, one process being distributed to the periphery and the other entering the spinal cord or brain-stem. The peripheral process in some instances enters into relation with sensory end-organs, which are the specific receptors for certain forms of sensibility. The nerve-fibres concerned in the appreciation of pain appear to be devoid of end-organs and to terminate as free nerve-endings. The receptors for heat and cold are not evenly distributed throughout the skin, but are situated in localized heat and cold spots. No specific end-organs for temperature sensibility have as yet been discovered. Meissner's corpuscles are encapsulated end-organs which are probably concerned in the appreciation of light touch. The hairs are also tactile organs and the hair follicles are richly supplied with nerve endings. The Pacinian corpuscles are distributed to the deeper parts of the dermis and to the tendons, periosteum, and the neighbourhood of the joints. These are probably concerned in the appreciation of pressure, posture, and passive movement. In addition muscles and tendons possess specialized sensory end-organs—the muscle and tendon spindles.

Sensibility may be divided into somatic and visceral forms of sensation. Somatic sensibility again may be divided into exteroceptive and proprioceptive forms Exteroceptive sensibility is concerned with the appreciation of stimuli coming from outside the body and includes cutaneous sensibility and the special senses. Proprioceptive sensibility is the appreciation of the posture and movements of the body itself. Proprioceptive impulses are derived from the labyrinths and the muscles, tendons, and joints. Not all proprioceptive afferent impulses reach consciousness. Many are concerned in reflex activities at the spinal level or influence the cerebellum in its control of movement and posture.

Cutaneous Sensory Segmentation.

Primitive organisms frequently exhibit metameric segmentation of the body, and this arrangement is evident in the human foetus during the early stages of its development. Each somatic segment or metamere is linked to the corresponding segment of the neuraxis

by a pair of spinal nerves. In the course of evolution the specialization of the anterior end of the organism to form the head, and the growth of the complicated motor and sensory functions of the limbs have interfered with the primitive metameric segmentation of the nervous system, which in man is now found in its simplest form only in the thoracic region.

Each spinal nerve is formed by a fusion of one anterior and one posterior spinal root, the anterior root conveying efferent and the posterior mainly afferent fibres. The sensory character of the posterior roots was first recognized by Magendie in 1822. After this fusion the spinal nerve divides peripherally into its anterior and posterior primary divisions, both containing motor and sensory fibres. The posterior primary division conveys motor fibres to the muscles of the spine and sensory fibres to the overlying cutaneous area. The anterior primary division in its simplest form, for example, in the mid-thoracic region, supplies motor fibres to the intercostal muscles and sensory fibres to a narrow zone extending horizontally round the thorax on one side as far as the middle line. At the cervical and lumbo-sacral enlargements of the cord the arrangement is complicated by the formation of the limb plexuses, in which several of the anterior primary divisions unite and subsequently subdivide to form the peripheral nerves to the limbs. Through the intervention of the plexuses a single spinal nerve may send both motor and sensory contributions to several peripheral nerves, and, conversely, a single peripheral nerve may receive contributions from several spinal nerves. It follows that the *sensory loss resulting from interruption of a peripheral nerve differs in its distribution from that produced by interruption of a posterior root or spinal nerve.* A segmental or radicular cutaneous area is an area of skin which receives its sensory supply from a single posterior root and spinal nerve. In the trunk these segmental areas still exhibit a metameric arrangement. In the limbs this has been modified, but as a rule the segmental areas occupy elongated zones in the long axis of the limb (Figs. 4 and 5). Owing to the specialization of the anterior primary divisions of the lower cervical and first thoracic spinal nerves in the innervation of the upper limb, these have lost their cutaneous supply to the trunk anteriorly, and at the level of the second rib the fourth cervical seg- *mental cutaneous area is contiguous with the second thoracic.* The lower six thoracic spinal nerves supply the abdominal wall as low as Poupart's ligament. Probably owing to the fact that the posterior primary divisions of the spinal nerves take no part in the formation of the limb plexuses, all spinal segments appear to be represented in the cutaneous supply of the back.

There is considerable overlapping of contiguous segmental cuta-

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There is considerable overlapping of contiguous segmental cuta-

neous areas, hence the division of a single posterior root does not cause any sensory loss detectable by ordinary clinical methods (Foerster). There is evidence that each root supplies fibres for pain,
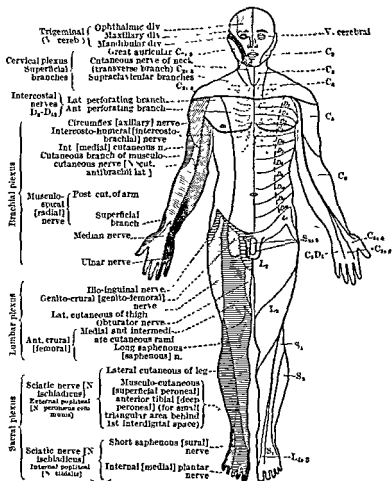
FIG. 4   Diagram to show Cutaneous Areas of Distribution of Spinal Segments and the Peripheral Nerves

(Rauchet and Dupret, *Pocket Atlas of Anatomy*).

heat, and cold to a larger area than that to which it supplies fibres for light touch.

In the sensory innervation of the head the trigeminal nerve represents a fusion of the sensory supply of several segments, though the

seventh, ninth, and tenth cranial nerves still possess rudimentary
sensory branches distributed to the neighbourhood of the auricle.
The posterior and inferior boundary of the trigeminal cutaneous area
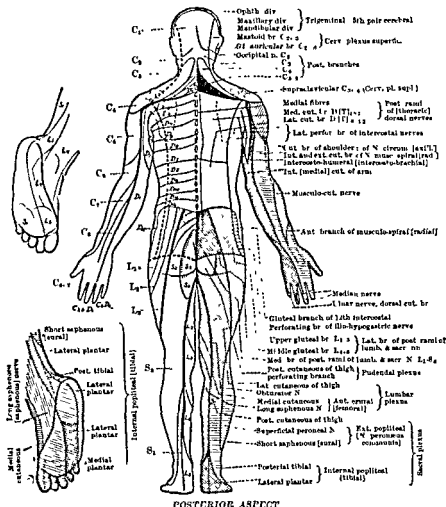
Fig. 5. Diagram to show Cutaneous Areas of Distribution of Spinal Segments
and the Peripheral Nerves.

(Fauvel and Dupret, Pocket Atlas of Anatomy.)

is contiguous with those of the first and second cervical segments
respectively.

SENSORY PATHS IN THE SPINAL CORD

As we have seen, all sensory fibres from the limbs and trunk enter
the spinal cord by the posterior roots. After entering the cord these

incoming fibres lie on the medial side of the apex of the posterior horn of grey matter, in the outer part of the tract of Burdach, where they divide into ascending and descending branches. The descend-
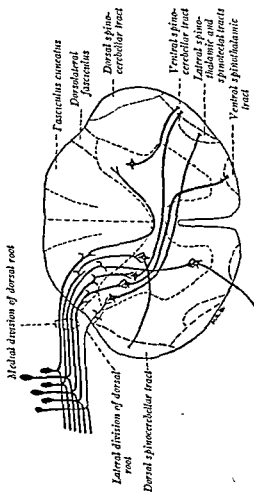
Fig. 6. Diagram of the spinal cord and dorsal root, showing the divisions of the dorsal root, the collaterals of the dorsal root fibres, and some of the connexions which are established by them.
(Ranson, *Anatomy of the Nervous System*)

Note. The lateral and ventral spino-thalamic tracts are also called the posterior and anterior spino thalamic tracts respectively.

ing branches, which form the comma tract, terminate in the grey matter after passing downwards through a few segments. The ascending fibres pass upwards in the lateral part of the posterior column. They may be divided into three groups in accordance with their respective distributions (Fig. 6)

(1) Some of these fibres continue to pass upwards in the posterior column of the same side and terminate in the medulla in the nuclei

gracilis and cuneatus. In their upward course the fibres of lowest origin pass gradually towards the middle as they are joined on their outer side by fibres from higher roots. Thus the fibres from the sacral roots come to lie nearest the middle line, with those from the lumbar roots to their lateral side, and fibres from the cervical roots are the most laterally placed. Those fibres ultimately derived from the lower limb pass upwards in the column of Goll, while those from the upper limb are found in the column of Burdach. The fibres of the posterior column convey impulses concerned with the appreciation of posture and passive movements of the joints and of the vibration of a tuning-fork, and with tactile discrimination, that is, the ability to recognize as two the points of a compass when simultaneously applied. It is probable that some fibres concerned with the sensation of light touch and its localization also pass up in the posterior column as far as the medulla.

(2) The second group of entering fibres pass up in the posterior column of the same side for a considerable distance, but ultimately enter the posterior horn of grey matter, round the cells of which they terminate. From these cells further fibres take origin and cross the middle line in the grey and anterior white commissures to reach the opposite anterior column. There they turn upwards and constitute the ventral spino-thalamic tract. These are the remaining fibres concerned in the appreciation of light touch and its localization.

(3) The remaining fibres of the posterior roots are those which ascend in the posterior column for the shortest distance, usually through only about three segments and never through more than five or six. They also end among the cells of the posterior horn from which fibres of the second relay take origin and, crossing the middle line, like those of the previous group, enter the antero-lateral column more posteriorly, and turning upwards constitute the dorsal spino-thalamic tract. These fibres conduct impulses concerned with the appreciation of pain, heat, and cold. There is some evidence that there exists a lamination of the fibres of the dorsal spino-thalamic tract similar to that of the posterior columns, and that the fibres which convey sensation from the most caudal areas lie in the posterior part of each tract and those entering at higher levels lie more anteriorly and internally.

Non-sensory Afferent Impulses.

To complete our account of the destinations of the fibres entering the spinal cord by the posterior roots we must mention two groups of fibres which are not concerned with sensation since they do not conduct impulses to consciousness, namely, those which are relayed upwards in the dorsal and ventral spino-cerebellar tracts. The end-

organs of these fibres are probably mainly, if not exclusively, the proprioceptors of the muscles and tendons, and it is possible that the spino cerebellar tracts are supplied from collaterals of the fibres of the posterior columns. However that may be, those impulses which are destined for the dorsal spino-cerebellar tract run at first in the lateral part of the posterior column and terminate around the cells of Clarke's column, which occupies the medial aspect of the base of the posterior horn of grey matter, from the seventh cervical to the second lumbar segment. From Clarke's column fibres turn outwards to run up in the posterior part of the periphery of the lateral column on the same side, constituting the dorsal spino-cerebellar tract and reaching the cerebellum by the restiform body of the same side. The ventral spino-cerebellar tract is said to be derived from cells of the posterior horn of grey matter on the same and the opposite side. It lies in the antero-lateral column ventral to the dorsal spino-cerebellar tract and runs up as far as the midbrain before turning downwards to reach the cerebellum by way of the superior peduncle. There is reason to believe that the dorsal spino-cerebellar tract receives impulses from the lower limbs and the trunk, and the ventral spino-cerebellar tract mainly from the upper limbs. These impulses do not reach consciousness, but provide much of the 'raw material' of proprioceptor information which guides the activities of the cerebellum. Their existence explains why lesions of the posterior roots and spinal cord may cause ataxia without gross loss of postural sensibility.

Brown-Séquard's Syndrome.

Hemisection of the cord is a rare occurrence, but a lesion mainly involving one half is not uncommon. Destruction of the posterior column causes loss of appreciation of posture and passive movement of the joints, of the vibration of a tuning-fork, and of tactile discrimination below the level of the lesion. Destruction of the posterior spino-thalamic tract causes analgesia and thermo-anaesthesia on the opposite side of the body. Since fibres entering this tract do not cross the cord for several segments, the upper level of this sensory loss is likely to be a few segments below the level of the lesion. Conversely the fibres entering the cord just below the lesion may be caught before they cross, causing a narrow zone of similar analgesia and thermo-anaesthesia immediately below the lesion on the same side. Owing to the double route of fibres for light touch and tactile localization, partly crossed and partly uncrossed, there is rarely any loss of these forms of sensibility after a unilateral lesion of the cord. Any ataxia which might result from interruption of the spino-cerebellar tracts is likely to be masked by that resulting from loss

of posterior column sensibility. Hemisection of the cord of course interrupts descending as well as ascending tracts, and the clinical picture therefore includes the signs of pyramidal defect below the lesion; and destruction of the anterior horn causes a lower motor neurone lesion with a segmental distribution corresponding to the level of the lesion The signs of this are likely to be conspicuous only when the lesion occurs at the cervical or lumbar enlargements.

SENSORY PATHS IN THE BRAIN-STEM

The two principal modifications in the arrangements of the sensory fibres which distinguish the brain-stem from the spinal cord are the entrance of the trigeminal nerve and the decussation of the fillet. The central connexions of the trigeminal nerve are described elsewhere (see p 153). In summary it may be said that fibres concerned in the appreciation of pain, heat, and cold in one trigeminal area, after entering the spinal tract and nucleus of the fifth nerve, cross to the opposite side of the medulla and ascend in close relationship with the median fillet joining the spino-thalamic tract in the pons

The fibres of the posterior columns of the spinal cord have already been traced to their termination in the nuclei gracilis and cuneatus in the posterior part of the medulla. From these nuclei the second fibres of this sensory path take origin and cross to the opposite side as the internal arcuate fibres or the sensory decussation. After decussating they occupy a position on either side of the middle line as the median fillet and so pass upwards through the brain-stem, to reach the optic thalamus. The median fillet is joined in the pons by fibres from the principal sensory nucleus of the trigeminal nerve which are concerned in the appreciation of light touch, pressure, and postural sensibility of the trigeminal area.

Throughout the brain-stem the spino-thalamic tract, with which, above the medulla, is associated the quinto-thalamic tract, lies in the tegmentum, external to the median fillet. As a result of this arrangement lesions involving the lateral part of the tegmentum of the brain-stem are likely to cause hemianalgesia and thermo-anaesthesia on the opposite side of the body, leaving postural sensibility and appreciation of passive movement and tactile discrimination intact. When the lesion is situated in the medulla, below the point at which the spino-thalamic tract has been joined by the quinto-thalamic tract, analgesia and thermo-anaesthesia involve the opposite side of the body below the face only, while similar sensory loss is likely to occur on the face on the side of the lesion, owing to damage to the spinal tract and nucleus of the trigeminal nerve. Appreciation of pain, heat, and cold are frequently affected to a different extent by

lesions of the brain-stem. Deeply seated lesions may involve the medial fillet without the spino-thalamic tract, thus producing loss of postural sensibility, of appreciation of passive movement and of tactile discrimination on one or both sides of the body, but leaving appreciation of pain, heat, and cold unimpaired. Massive lesions, such as tumours, are likely to involve all forms of sensibility, though often to a varying extent. In the midbrain the third nerve and red nucleus may be simultaneously involved, leading to Benedikt's syndrome—paralysis of the third nerve on one side with hemianaesthesia and tremor on the opposite side.

THE OPTIC THALAMUS

All sensory fibres pass upwards from the brain-stem to the optic thalamus, whence many are redistributed in a further relay to the cerebral cortex (p. 4). Since certain forms of sensibility are unimpaired after lesions of the cerebral cortex, it has been argued that for these the optic thalamus must constitute the end-station. These forms of sensation include the qualitative element in the appreciation of pain, heat, and cold, and the affective element, that is the pleasant or unpleasant character, of other forms of stimuli. Lesions in and near the optic thalamus are likely to cause loss of various forms of sensibility owing to interruption of the fibres upon which they depend. In addition peculiarities of sensory response, the interpretation of which has given rise to much discussion, occasionally occur.

Sensory Loss.

A severe and extensive lesion of the optic thalamus may cause gross impairment of all forms of sensibility on the opposite side of the body, probably as a result of damage to the ventral nucleus (Ajuriaguerra). Less severe lesions may cause less serious sensory disturbance. Appreciation of posture and passive movement usually suffer severely. Appreciation of light touch and its localization are also often impaired. Appreciation of heat and cold may be impaired, both forms of sensibility being affected together, though not always to an equal extent. The threshold for pain may be normal, but is frequently raised, even when painful stimuli cause an exaggerated response.

Thalamic 'Over-reaction'.

This sensory abnormality which may follow lesions of the thalamus is comparatively rare, at least in a fully developed form. It is generally agreed that damage to the lateral nucleus is necessary for it to occur. Pain of central origin may be referred to the opposite side of

the body. It may be extremely severe and fail to respond to analgesic drugs, including morphine. Although the threshold to sensory stimuli is usually raised on the affected half of the body, yet such stimuli, when they are effective, excite sensations of a peculiarly unpleasant character. This combination of a raised threshold with over-reaction is known as 'hyperpathia'. The painful stimulation of superficial and deep tissues and of the viscera excites more severe pain on the affected than on the normal side. Extremes of heat and cold similarly excite a feeling of great discomfort on the affected side, and the same is true of such stimuli as scraping, tickling, and a vibrating tuning-fork. Exceptionally, pleasurable stimuli, such as pleasant warmth, have been found to cause increased pleasure on the affected side, and this half of the body has been said to react to emotional states in a manner different from the normal half.

Other symptoms which have been attributed to a lesion of the optic thalamus include choreo-athetoid movements with slight ataxia and hemiparesis on the opposite side of the body, but it is uncertain whether these symptoms are due to involvement of the thalamus itself or to injury of adjacent regions of the basal ganglia.

Thalamic over-reaction is most often seen after vascular lesions, and is rare with other types of lesion. Its nature has been much discussed and it has been attributed by some workers to irritation of the thalamus, by others to its escape from cortical control. The phenomenon of over-reaction to painful stimuli associated with a raised threshold to such stimuli is not a symptom of thalamic lesions only. It may, in fact, be observed as a result of a lesion involving pain-fibres at any point between their endings in the skin and deeper tissues and the optic thalamus. Thus it occurs in the so-called proto-pathic phase of sensibility during regeneration of a peripheral sensory nerve and as a result of lesions of the spino-thalamic tract within the spinal cord and brain-stem. It may be the outcome of defective insulation of the pain-fibres at any point of their course, whereby conduction of painful impulses is to some extent impaired, but at the same time there is a tendency to irradiation which causes a localized stimulus to evoke a diffuse and exaggeratedly painful sensation. Nevertheless, there is much to be said for the view that in thalamic cases there is also a loss of cortico-thalamic inhibition.

SENSATION AT THE SUBCORTICAL LEVEL

A lesion involving the sensory fibres between the optic thalamus and the cerebral cortex usually causes severe and extensive sensory loss, since the fibres are here more closely crowded together than at the cortex. The appreciation of the qualitative element in pain, heat, and cold is unimpaired if the thalamus is undamaged. Other

forms of sensibility are usually severely affected, there being as a rule marked loss of appreciation of posture, passive movement, tactile localization and discrimination, and of the appreciation of size, shape, and form. There may be an impairment of appreciation of temperatures in the middle of the thermal scale. A patient with a subcortical lesion does not exhibit the variability of response and threshold which characterizes patients with cortical lesions.

SENSATION AT THE CORTICAL LEVEL

As Head and his collaborators have shown, the cerebral cortex is concerned essentially with the spatial and discriminative elements of sensibility. The extent of the cerebral cortex concerned in sensation and the localization therein of different forms of sensory appreciation is somewhat uncertain. There is no doubt that the post-central convolution is concerned in the appreciation of the posture and passive movements of the opposite half of the body, parts of which are represented there in a manner similar to their representation for purposes of motility in the precentral convolution (see p. 2). It is probable that the greater part of the parietal lobe behind the post-central convolution is also concerned in sensibility, but whether the sensory cortex extends in front of the fissure of Rolando is doubtful.

One striking feature of a lesion of the sensory cortex is the extreme variability of the patient's response to sensory stimuli and the difficulty or impossibility of obtaining a threshold. The appreciation of posture and of passive movement is frequently seriously impaired, together with the appreciation of light touch and its accurate localization and the discrimination of the duality of two compass-points. The appreciation of size, shape, form, roughness, and texture often suffers. The qualitative element in pain, heat, and cold is still recognized, but in dealing with thermal stimuli in the middle of the scale the patient may find it difficult to say which of two is the hotter

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4. THE REFLEXES

GENERAL CONSIDERATIONS

A reflex is the simplest form of involuntary response to a stimulus. The anatomical basis of a reflex is the reflex arc, which consists of (1) a receptor organ, (2) an afferent path running from the periphery to the brain-stem or spinal cord, (3) one or more intercalated neurones in the central nervous system linking the afferent path to (4) the efferent path which leaves the neuraxis by the lower motor neurones to reach (5) the effector organ. The reflex is elicited by a stimulus which may be a touch, a prick, the sudden stretching of a muscle, or some other event which excites an afferent impulse on the reflex arc. The response is a muscular contraction, a modification in muscle tone, glandular secretion, &c., depending upon the nature of the reflex. Important though visceral reflexes are, the neurologist investigating the state of the nervous system is mainly concerned with reflexes which excite responses in the somatic musculature.

Reflex action was first observed by Stephen Hales in a pithed frog about 1730. The conception was elaborated by Robert Whytt in 1755, and later by Marshall Hall in 1833.

A reflex is fundamentally dependent upon the integrity of its reflex arc. Lesions which interrupt this arc at any point cause abolition of the reflex. Loss of a reflex may thus be brought about by interruption of the afferent path by a lesion involving the first sensory neurone in the peripheral nerves, plexuses, spinal nerves, or posterior roots, by damage to the central paths of the arc in the brain-stem or spinal cord, or by lesions of the lower motor neurone at any point between the anterior horn cells and the muscles, or of the muscles themselves. The strength of a reflex muscular contraction is influenced by the state of the antagonistic muscles. If these are weak the contraction of the prime movers is enhanced. If the antagonists are in tonic contraction, as, for example, in Parkinsonism, the amplitude of the movement normally effected by the prime movers is restricted.

A painful lesion tends to increase the vigour of the reflex activity of neighbouring muscles, probably because the incoming stream of painful impulses increases the excitability of the corresponding segments of the spinal cord. Somewhat similarly, one reflex may exert either a reinforcing or an inhibitory effect on another. For example, the flexor withdrawal reflex in the lower limbs in paraplegia tends to inhibit the knee- and ankle-jerks. Higher levels of the nervous system also exert important reinforcing and inhibitory influences upon reflex activities, examples of which will be encountered later.

REFLEXES INVOLVING THE CRANIAL NERVES

(i) *The Pupillary Reflexes* are described on p. 80.

(ii) *The Corneal Reflex.* The stimulus which evokes the corneal reflex is a light touch upon the cornea, e.g. with a wisp of cotton-wool, and the response is bilateral blinking. The afferent path is through the first division of the fifth cranial nerve; the central path consists of fibres uniting the spinal nucleus of the fifth nerve with both facial nuclei, and the efferent path passes through the facial nerves to both orbiculares oculi muscles A lesion involving the fifth nerve or its spinal nucleus, since it interrupts the afferent path, causes bilateral loss of blinking in response to stimulation of the cornea on the side of the lesion A lesion involving the nucleus or fibres of the seventh nerve interrupts the efferent path and hence causes loss of the reflex on the side of the lesion only, and blinking occurs on the opposite side. Loss of the corneal reflex is often an early sign of a lesion of the fifth nerve and may occur before any cutaneous anaesthesia can be detected. Apart from lesions involving the reflex arc, the corneal reflex is lost in states of deep coma, and sometimes also in hysteria

(iii) *The Jaw Jerk.* In response to a tap upon the chin, depressing the lower jaw, there is a bilateral contraction of the elevators of the jaw. Both afferent and efferent paths pass through the trigeminal nerve This reflex is physiologically allied to the tendon reflexes, and, like these, becomes exaggerated as a result of bilateral pyramidal lesions

(iv) *The Sucking Reflex* In the infant the contact of an object with the lips evokes the movements of the lips, tongue, and jaw concerned in sucking. This sucking reflex is lost after infancy but may reappear in states of severe cerebral degeneration, for example, the presenile and senile dementias.

(v) *The Palatal Reflex.* The palatal reflex consists of elevation of the soft palate in response to a touch. The afferent path is by the second division of the fifth nerve; the efferent by the vagus. The palatal reflex is variable in intensity in normal individuals, and is sometimes absent in hysteria. It is abolished by lesions causing anaesthesia of the palate and by lesions of the vagus nuclei, and in lesions of one vagus nerve the response is unilateral and the uvula is displaced towards the normal side.

(vi) *The Pharyngeal Reflex.* The pharyngeal reflex consists of constriction of the pharynx in response to a touch upon the posterior pharyngeal wall. Its afferent path runs in the glossopharyngeal nerve, its efferent path in the vagus. Like the palatal reflex, it is abolished by lesions causing pharyngeal anaesthesia and by lesions

of the vagus nuclei, and is sometimes absent in hysteria. In cases of unilateral paralysis of the vagus the response is confined to the opposite half of the pharynx.

REFLEXES OF THE LIMBS AND TRUNK

(1) The Tendon Reflexes.

A so-called 'tendon reflex' is a sharp muscular contraction evoked by suddenly stretching the muscle. The sudden stretch may be brought about by tapping the tendon, or by suddenly displacing the segment of a limb into which the muscle is inserted. The response, a muscular contraction, is most evident in the muscle stretched, but may not be confined to this muscle. A tendon reflex is diminished or abolished by a lesion interrupting either the afferent, central, or efferent paths of the reflex arc. Higher levels of the nervous system also influence the excitability of the tendon reflexes. This is enhanced by anxiety and by lesions of the pyramidal tracts. It is diminished by neural shock and by increased intracranial pressure. They may be congenitally absent. The following table gives the principal tendon reflexes, their mode of elicitation and their innervation.

Reflex	Mode of elicitation	Response	Spinal segment	Peripheral nerve
Biceps jerk	A blow upon the biceps tendon	Flexion of the elbow	Cervical 5–6	Musculo-cutaneous
Triceps jerk	A blow upon the triceps tendon	Extension of the elbow	Cervical 6–7	Musculo-spiral
Supinator jerk or Radial reflex	A blow upon the styloid process of the radius	Flexion of the elbow	Cervical 5–6	Musculo-spiral
Knee jerk	A blow upon the quadriceps tendon	Extension of the knee	Lumbar 2–4	Anterior crural
Ankle jerk	A blow upon the tendo Achillis	Plantar flexion of the ankle	Sacral 1–2	Sciatic

Clonus, a rhythmical series of contractions in response to the maintenance of tension in a muscle, *is often elicitable when the ten-don reflexes are exaggerated after a pyramidal lesion.* Clonus of the quadriceps, patellar clonus, *is best elicited by a sudden sharp down-ward displacement of the patella.* Ankle clonus is obtained by sharply dorsiflexing the ankle. Clonus of the flexors of the fingers can sometimes be obtained in response to stretching these muscles by extending the fingers

(2) Cutaneous Reflexes.

(i) *The Abdominal Reflexes.*

These are cutaneous reflexes consisting of a brisk contraction of a segment of the abdominal wall in response to a cutaneous stimulus, such as a light scratch with a pin. It is convenient to elicit them at three levels on each side, just below the costal margin, at the level of the umbilicus, and at the level of the iliac fossa. The response is mainly segmental, being maximal at the level of the stimulus. Although the abdominal reflexes probably utilize a short spinal reflex arc they are normally dependent, for a reason which is not fully understood, upon the integrity of the pyramidal tract. Hence a pyramidal lesion is usually associated with diminution or loss of the abdominal reflexes upon the same side. In the case of a slight degree of pyramidal defect the reflexes may be reduced in vigour but not completely abolished. In such cases the reflexes of the lowest segments suffer most. Abdominal reflexes which have at one time been lost may return later, although the pyramidal lesion persists. The loss of the abdominal reflexes is not always proportional to the severity of the pyramidal lesion. In disseminated sclerosis, for example, the abdominal reflexes may be lost early, at a stage of the disease when other signs of pyramidal lesions are slight. In congenital diplegia, on the other hand, the abdominal reflexes are usually brisk.

The reflex arcs of the abdominal reflexes are localized in the spinal cord from the seventh to the twelfth dorsal segments. Lesions involving the arcs themselves may produce diminution or loss of the reflexes. The commonest such lesion is damage to the lower motor neurone by acute anterior poliomyelitis. Little importance can be attached to diminution of the abdominal reflexes in stout people, after repeated pregnancies, and after middle life.

(ii) *The Cremasteric Reflex.*

The cremasteric reflex is a cutaneous reflex closely related to the abdominal reflexes. The appropriate stimulus is a light scratch along the inner aspect of the upper part of the thigh, and the response is a contraction of the cremaster muscle, with elevation of the testicle. This reflex, the arc of which runs through the first lumbar spinal segment, is diminished or abolished by a lesion of the pyramidal tract. It is usually extremely brisk in children, in whom it may sometimes be elicited by a stimulus applied to any part of the lower limb. It is usually absent in a patient with varicocele.

(iii) *The Gluteal Reflex.*

The gluteal reflex is physiologically akin to the abdominal reflexes. A scratch on the buttock evokes contraction of the glutei. The spinal segments concerned are lumbar 4 and 5

(iv) *The Plantar Reflex.*

The plantar reflex is one of the most important of all reflexes to the neurologist, because its meaning is unequivocal.

The Flexor Plantar Reflex. The flexor plantar reflex is normal after the first year of life. The stimulus which evokes it is a scratch upon the sole of the foot, and the response is plantar flexion of the toes usually associated with dorsiflexion of the foot at the ankle, contraction of the tensor fasciae femoris muscle, and other variable muscular contractions. Its significance is obscure, but it appears to be a spinal segmental reflex mediated by the first sacral segment of the cord and akin to the abdominal reflexes.

The Extensor Plantar Reflex. Babinski in 1896 first pointed out that in the presence of a pyramidal lesion the normal flexor plantar reflex did not occur, but its place was taken by an upward, extensor movement of the great toe   Further investigation by Riddoch, Walshe, and others has shown that the extensor plantar reflex is not an isolated phenomenon, but is part of a general reflex flexion of the whole lower limb, homologous with the flexion reflex of the spinal animal in response to a noxious or potentially painful stimulus. The afferent focus, i e the region of easiest elicitation of this reflex, is the outer border of the sole. The motor focus, or minimal response, is a contraction of the inner hamstring muscles. In its fully developed form the reflex consists of flexion at all joints of the lower limb with dorsiflexion of the great toe and abduction or fanning of the other toes.

Confusion has arisen from the application of the term extensor plantar reflex to a movement which forms part of a flexor reflex of the lower limb. The explanation of this misnomer is that the extensor longus hallucis muscle, though named extensor by the anatomists, is in fact a flexor muscle, since its action is to shorten the limb, and it contracts reflexly in association with other flexor muscles. The term extensor plantar reflex, however, appears to be too firmly established to be altered. 'Positive Babinski reflex' and 'upgoing toe' are alternative terms which are sometimes employed.

Physiological understanding illuminates several points of practical importance in the elicitation of the plantar reflex. The stimulus should always be applied to the outer border of the sole. Since this is the afferent focus of the reflex arc, an extensor response may sometimes be obtained from this region when the inner border of the sole yields

a flexor response. The reflex may be more easily obtained after the limb has been passively flexed than when it is lying fully extended. Oppenheim's reflex, dorsiflexion of the great toe, evoked by firm moving pressure on the skin over the tibia, is physiologically the same as Babinski's reflex, differing only in the site of the stimulus.

An extensor plantar reflex is often observed during sleep and deep coma from any cause, after epileptic fits, and usually in the first year of life, that is, when the pyramidal fibres are either functionally depressed or incompletely developed. In any other circumstances it indicates an organic lesion of the pyramidal tract.

(v) *Nociceptive Reflexes of the Upper Limb.*

Riddoch and Buzzard have demonstrated in the upper limb nociceptive reflexes which appear to be homologous with the flexor withdrawal reflex of the lower limb. These may be either flexor or extensor, the former being commoner in hemiplegia and the latter in quadriplegia. The area from which these reflexes are elicitable comprises the palmar surface of the fingers, the inner aspect of the forearm and arm, the walls of the axilla, and the upper part of the chest. The flexor reflex, of which the focus is the palm of the hand, consists of abduction and external rotation at the shoulder, and flexion at the elbow, wrist, and finger-joints. The extensor reflex, most easily elicited from the axillary walls, is composed of elevation, retraction, adduction, and internal rotation at the shoulder, extension at the elbow, pronation of the forearm, flexion of the wrist, and hyperextension and adduction of the fingers. These reflexes, like others of a nociceptive character, are elicited by painful stimuli such as scratching, pricking, or pinching.

(vi) *The Bulbo-cavernosus Reflex.*

The bulbo-cavernosus reflex consists of contraction of the bulbocavernosus muscle, which can be detected by palpation, in response to squeezing the glans penis. The spinal segments concerned are sacral 2, 3, and 4. This reflex is frequently abolished in tabes and in lesions of the cauda equina.

(vii) *The Anal Reflex*

The anal reflex consists of contraction of the external sphincter ani in response to a scratch upon the skin in the perianal region. The spinal segments concerned are sacral 4 and 5.

(3) Postural Reflexes.

'Postural reflexes' is a convenient term to apply to reflexes in which the response consists not of a brief muscular contraction but of a

sustained modification in the posture of one or more segments of the body.

Tonic Neck Reflexes. In the decerebrate animal it was found by Magnus and de Kleijn that changes in the position of the head relative to the body caused reflex modifications of the tonus and posture of the limbs. These reflexes, which are excited from the proprioceptors of the cervical spine, are known as *tonic neck reflexes* and may sometimes be observed in hemiplegia. Rotation or lateral flexion of the head towards the paralysed side causes extension or increased extensor tonus of the paralysed limbs; rotation or lateral flexion to the normal side increases their flexor tonus. The tonic neck reflexes are often facilitated if the patient grasps the observer's hand firmly with his normal hand.

Tonic Labyrinthine Reflexes. Similarly changes in the tone of the limb muscles may be excited from the labyrinthine proprioceptors by changes of the position of the patient in space, but these are of insufficient importance to be described in detail

Associated Reactions, or associated movements, are automatic modifications of the posture of parts of the body when vigorous voluntary or reflex movement of some other part occurs. They are best observed in the paralysed upper limb in hemiplegia, though they may also occur in the trunk and lower limb. Following a vigorous grasping movement with the sound hand there is usually *an increase of tone in the muscles of the paralysed limbs which pre*dominates in the flexors of the upper and the extensors of the lower limb. The result is a slow flexor excursion of the paralysed forearm, wrist, and fingers, with abduction, adduction, or elevation of the shoulder, the resulting new posture being maintained until the grasp is relaxed. Other patterns of associated movement occur. Such semi-voluntary activities as yawning, stretching, and coughing often evoke associated movements in the paralysed limbs in hemiplegia, and may arouse in the patient or his friends false hopes of recovery.

The Quadrupedal Extensor Reflex of the upper limb is an associated movement of extension of the flexed upper limb in hemiplegia or diplegia, which may sometimes be evoked by causing the patient, when standing or kneeling, to lean forward and throw his weight on to the observer's supporting hand placed beneath his chest.

(4) Forced Grasping and Groping.

The Grasp Reflex of the Hand. In certain patients the contact of an object with the palmar surface of the fingers, especially the region between the thumb and the index finger, causes reflex flexion of the fingers and thumb so that the hand involuntarily grasps the object The patient is unable voluntarily to relax his grasp, and efforts to

pull the object away only result in an increase in its strength. Often he notices that when he is holding an object he is unable to relinquish his hold of it in order to put it down. This phenomenon is known as forced grasping, or the grasp reflex. In some cases, when the patient's eyes are closed, if the palmar surface of the hand or fingers is lightly touched, the hand and arm move towards the stimulus and in this way may be drawn in any direction—forced groping. Even an object presented to vision may be groped for, but this cannot be reflex, but is a phenomenon of a higher order.

Forced grasping and groping, which have been considered a regression to the infantile stage of the function of grasping, usually indicate a lesion involving the upper part of the medial aspect of the opposite frontal lobe. The commonest causes are neoplasms and vascular lesions. In rare cases the cause has been a tumour in some other part of the brain, but in such instances the functions of the frontal lobe have probably been impaired by increased intracranial pressure. A unilateral grasp reflex in a fully conscious patient is of localizing value. When the reflex is bilateral or the patient semiconscious its value is much less. When the causative lesion produces a progressive hemiplegia, the grasp reflex disappears when paralysis becomes complete, which appears to indicate that it utilizes the pyramidal tract as part of its motor path.

The Grasp Reflex of the Foot. An allied grasp reflex may sometimes be observed in the foot, light pressure or a stroking movement applied to the distal half of the sole and plantar surface of the toes evoking tonic flexion and adduction of the toes without other associated movements. Like the fingers, the toes may grasp and hold an object. This reflex is present in the normal infant up to the end of the first year, and in 50 per cent. of Mongolian imbeciles. It may occur also, either with or without the hand-grasp reflex, in patients with lesions of the upper part of the medial aspect of the opposite frontal lobe.

(5) Other Reflexes and Reactions.

Mayer's Reflex. Mayer has described a reflex which is present in normal persons but disappears after a pyramidal lesion. With the hand supinated, passive flexion of the fingers at the metacarpophalangeal joints evokes adduction and opposition of the thumb with flexion at its metacarpo-phalangeal and extension at its interphalangeal joint. Exaggeration of Mayer's reflex has been observed in meningitis and in cases of intracranial tumour giving rise to a grasp reflex.

Wartenberg's Sign. If a normal individual is made to flex the terminal phalanges of his fingers against the resistance offered by the observer's fingers similarly flexed, his thumb remains abducted and

extended. Following a pyramidal lesion, however, the thumb becomes strongly adducted and flexed. This sign is a useful indication in the upper limb of a slight pyramidal lesion. In hemiparesis the contrast between posture of the thumb on the affected and on the normal side may be striking.

Hoffmann's Reflex. The patient's hand is pronated and the observer grasps the terminal phalanx of the middle finger between his forefinger and thumb. With a sharp flick the phalanx is passively flexed and suddenly released. *A positive response consists of a sharp twitch of adduction and flexion of the thumb and flexion of the fingers.* This reflex is probably an index of muscular hypertonia rather than of a pyramidal lesion as such It is not always positive in the presence of such a lesion, and may be elicitable in a nervous individual with no organic disease.

Rossolimo's Reflex, in which a blow on the ball of the foot with a patellar hammer elicits flexion of the toes, and the *Bechterew-Mendel Reflex,* in which the same response follows a tap on the cuboid bone, are sometimes present in cases of a pyramidal lesion, but should not be regarded as pathognomonic of this. Probably Hoffmann's, Rossolimo's, and the Bechterew-Mendel reflex are all reflex muscular contractions evoked by sudden stretching. In states of muscular hypertonia this response may spread beyond the muscles stretched, as when a tap on the styloid process of the radius elicits a contraction not only of the supinator longus, but also of the long flexors of the fingers.

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5 THE CEREBELLUM

ANATOMY AND MORPHOLOGY

The cerebellum is situated in the posterior fossa of the skull and is
joined to the brain-stem by three peduncles, the superior, middle, and
inferior Above is the tentorium cerebelli and below it is separated
from the posterior aspect of the medulla and the dura mater cover-
ing the occipito-atlantal ligament by a dilatation of the subarach-
noid space, the cisterna magna. To the naked eye it is composed of
three main divisions, two lateral lobes and a median lobe, the *vermis*,
but this is not a morphological division.

Phylogeny and experimental physiology provide a sounder basis
for morphology According to Larsell (1937) and Fulton and Dow
(1937–8) the cerebellum has two primary divisions: (1) the flocculo-
nodular lobe, the most primitive part, with connexions which are
entirely vestibular, and (2) the corpus cerebelli, itself divided into
(i) a palaeocerebellar division, receiving vestibular and spino-
cerebellar fibres, and composed anteriorly of lingula, centralis, and
culmen, and posteriorly of pyramis, uvula, and paraflocculi, and (ii)
a neocerebellar division, constituting the greater part of the corpus
cerebelli, with connexions mainly cortico-pontine.

The cerebellum consists mainly of white matter which is covered
with a thin layer of grey matter, the cerebellar cortex, and contains
several grey masses, the nuclei. These are divided into lateral nuclei,
the nuclei dentatus and emboliformis, and middle and roof nuclei,
the nuclei globosus and fastigii.

Microscopically the cortex consists of three principal layers of cells,
the molecular layer, which lies most superficially, the granular layer,
which is the deepest, and the layer of Purkinje cells, which lies between
the two In the three cortical layers are numerous fibres, impulses from
which probably ultimately impinge upon the dendrites of the Purkinje
cells The axones of the latter pass through the white matter of the
cerebellar hemispheres and are distributed chiefly to the dentate nuclei.

Afferent Fibres.

The cerebellum receives numerous afferent fibres which are principally derived from the proprioceptor organs of the body, namely:

(1) *Vestibular Fibres.* These are derived from the labyrinth and enter the cerebellum by the inferior peduncles, some being interrupted at the vestibular nuclei These go mostly to the cortex of the vermis.

(2) *Spinal Fibres.* These come from proprioceptors of the muscles and possibly also from the joints and tendons. They reach the cerebellum by the dorsal spino-cerebellar tract, which ascends in the posterior part of the lateral column of the spinal cord and enters the cerebellum by the inferior peduncle, and by the ventral spino-cerebellar tract, which passes up the cord in the antero-lateral column, ascends as high as the midbrain, and turns backwards to the cerebellum through the superior peduncle. The dorsal spino-cerebellar tract probably receives a contribution from the trigeminal nerve. Fibres from the spino-cerebellar tracts end throughout the cerebellar cortex.

(3) *Cortical Fibres.* Impulses reach the cerebellum from the cerebral cortex by way of the cortico-spinal tracts with a relay station in the nuclei of the pons, whence fibres pass to the cerebellum by the middle peduncle. They are distributed mainly to the middle lobes.

(4) *Olivary Fibres.* The inferior olive, which receives spinal and thalamic connexions, is intimately related to the opposite cerebellar hemisphere, to which it sends fibres through the opposite inferior peduncle. Atrophy of one cerebellar hemisphere is usually associated with atrophy of the opposite olive.

Most afferent fibres are distributed to the cerebellar cortex.

Efferent Fibres.

Efferent fibres take origin in the cerebellar nuclei and leave the cerebellum by all three peduncles. The most important outgoing path from the cerebellum passes from the dentate nucleus and from nuclei emboliformis and globosus through the superior peduncle and after decussation is distributed to the opposite red nucleus From the red nucleus arises the *rubro-spinal tract which decussates in the decussation of Forel* and passes down through the brain-stem to the lateral column of the spinal cord. This is probably the principal route by which the cerebellum influences the lower motor neurone. Each cerebellar hemisphere is thus linked principally with the same side of the body by means of a double decussation in the midbrain. Other fibres from the red nucleus through the ansa lenticularis reach

the optic thalamus and may thus bring the cerebellum into relationship with the basal ganglia and the cerebral cortex.

Other cerebellar efferent fibres reach the reticular formation of the midbrain, the pons, and the medulla by all three peduncles.

THE FUNCTIONS OF THE CEREBELLUM

Our earliest knowledge of the functions of the cerebellum was based upon Rolando's observations of the effects of removal of this organ in 1809. His observations were extended by Flourens in 1824. Luciani, in 1879, summarized the symptoms of cerebellar deficiency as asthenia, atonia, and astasia, that is, weakness and fatiguability, diminution of tone, and tremor and a staggering gait. Recent experiments have yielded more precise information concerning cerebellar functions. Rademaker described extensor hypertonia in the limbs after removal of the whole cerebellum and Sherrington found that cerebellar stimulation could inhibit decerebrate rigidity. Denny-Brown, Eccles, and Liddell by stimulating the cerebellar cortex imposed modifications upon pre-existing spinal reflexes and observed inhibition and excitation of both extensor and flexor muscles, and Miller and Banting made similar observations in stimulating the cerebellar nuclei. These physiological observations, together with clinical investigation of the effects of cerebellar lesions by Holmes and others, have established the view that the cerebellum is essentially a reinforcing and co-ordinating organ which plays an important part in graduating and harmonizing muscular contraction, both in voluntary movement and in the maintenance of posture.

SYMPTOMS OF CEREBELLAR DEFICIENCY IN MAN

The following are the principal effects of cerebellar lesions in man:

(1) Muscular Hypotonia.

Hypotonia is evident in the visible, palpable flaccidity of the muscles, in a diminished resistance to passive movements of the joints, and in the wide excursions occurring at the terminal joints when the limb is vigorously shaken. If the outstretched upper limb receives a sudden tap, it shows a greater displacement than a normal limb. When the lesion is confined to one cerebellar hemisphere the hypotonia is present only on the same side of the body.

(2) Disturbances of Posture.

Abnormal Attitudes. Following a unilateral cerebellar lesion the shoulder on the affected side is often held at a lower level than the normal shoulder and there may be scoliosis with the concavity towards

the side of the lesion. In standing the weight is thrown on the sound leg and the body is somewhat rotated, with the affected shoulder in advance of the sound one. In severe cases the patient is unable to stand without support and tends to fall towards the side of the lesion. When a lesion involves one cerebellar hemisphere the head is often rotated and flexed, so that the occiput is directed towards the shoulder on the side of the lesion. This rotated posture may be due either to cerebellar deficiency or to a coincident lesion of the vestibular tracts.

Static Tremor. Tremor develops if the patient attempts to maintain a limb in a fixed posture, probably owing to hypotonia of the agonists producing an irregular contraction of the muscles maintaining the attitude.

(3) Disorders of Movement.

Several factors combine to produce disturbances of voluntary movement after a lesion of the cerebellum. Muscular contractions are weak and more easily fatigued than normally. Moreover, they are of an irregular, intermittent character, and there is delay both in initiating and in relaxing contractions.

Dysmetria occurs, the range of the movement being inappropriate to its objective. Sometimes the harmonious synthesis of movements at different joints is lost, leading to the phenomenon known as 'decomposition of movements'. When a movement involves the whole arm, instead of its occurring to an appropriate extent at all joints simultaneously, one joint is moved before another.

Tremor occurs on voluntary movement, owing partly to faulty fixation and partly to the factors responsible for static tremor. Fine movements, for example movements of the fingers, suffer especially from inco-ordination due to cerebellar deficiency, and the patient may find it impossible to button his clothes.

Adiadokokinesis is the term applied to an inability to carry out alternating movements with rapidity and regularity. For example, the patient is asked alternately to pronate and supinate his forearms or to flex and extend his fingers. After a unilateral cerebellar lesion alternating movements are accomplished slowly and in a jerky, inco-ordinate fashion on the affected side.

The Rebound Phenomenon is a disturbance of movement probably due to muscular hypotonia. If a normal individual is asked to flex his elbow against resistance offered by the observer and his forearm is suddenly released, its excursion in the direction of flexion is quickly arrested by contraction of the triceps. Cerebellar deficiency delays this contraction, with the result that flexion of the elbow is unchecked and *the patient may hit himself in the face*

Associated Movements. After a lesion of the cerebellum the normal associated movements which occur on strong voluntary effort may be exaggerated. Vigorous grimaces may accompany speech after a lesion of the cerebellar vermis.

(4) Ocular Disturbances.

In the early stages of a unilateral cerebellar lesion there may be weakness of conjugate ocular deviation to the affected side, but this soon passes off. In cases of severe bilateral lesions, or if the vermis is affected, there may be a temporary impairment of conjugate movement in the vertical plane also.

'Skew deviation' of the eyes is occasionally observed for a few days after an acute cerebellar lesion. The eye on the affected side is deviated downwards and inwards, while the opposite eye is deviated outwards and upwards. This may be due either to cerebellar deficiency or to interference with the vestibular connexions elsewhere.

Nystagmus is usually present in cerebellar disease. It is most evident when the eyes are deviated horizontally. The slow phase consists of a deviation towards the point of central fixation and the quick phase of a sharp jerk of return to the original position. In the case of unilateral cerebellar lesions the amplitude of the nystagmus is greater and its rate slower when the eyes are deviated towards the side of the lesion than when they are displaced to the opposite side. Nystagmus is usually in the horizontal plane, but there is occasionally a rotatory element also. Nystagmus on vertical deviation is inconspicuous For a further discussion of nystagmus see p. 74.

(5) Disorders of Articulation and Phonation.

Disturbances of articulation and phonation are more likely to occur when a lesion involves the vermis than when it is confined to one lateral lobe. Articulation is jerky and explosive. The voice is often too loud, and the syllables tend to be separated from each other. At the same time individual syllables are slurred owing to defective formation of consonants. Considerable recovery of speech usually occurs in the case of unilateral lesions.

(6) Disorders of Gait.

The patient with a unilateral lesion tends to stagger towards the affected side and to deviate to this side in walking. This may be well demonstrated by asking him to walk round a chair. When he is turning towards the affected side he tends to fall into the chair, when to the normal side, to move away from the chair in a spiral. The affected lower limb is markedly ataxic. With lesions of the vermis the patient tends to fall backwards, and walking may be

impossible unless he is supported on both sides, in spite of good co-ordination of movements of the lower limbs when he lies in bed.

(7) Abnormalities of the Reflexes.

The cutaneous reflexes are unaffected by lesions of the cerebellum. The tendon reflexes, however, often exhibit a characteristic change, which is best seen in the 'pendular' knee-jerk. The knee-jerk is followed by a series of oscillations of the leg, which are normally prevented by the after-shortening of the quadriceps.

(8) Bárány's Pointing Test.

The patient, with his eyes closed and one arm outstretched, is asked to move the limb in a given plane and bring his finger back to its original position. Deviation of the limb occurs after a unilateral cerebellar lesion and is most conspicuous when the movement takes place in the vertical plane, the arm deviating outwards on the side of the lesion.

LOCALIZATION IN THE CEREBELLUM

Some workers have claimed that there is a considerable localization of parts of the body in circumscribed areas of the cerebellum. The evidence for this is at present inconclusive. Movements and postures of the axis of the body, including articulation, standing and walking, appear to be represented predominantly in the vermis, while isolated movements of the limbs are represented predominantly in the ipsilateral hemisphere. Whether any more precise localization occurs is doubtful.

ACUTE AND CHRONIC LESIONS

The symptoms of a cerebellar lesion differ markedly in severity according to whether it develops rapidly or slowly. Most of our knowledge of the symptoms of cerebellar deficiency is based upon studies of acute lesions. When the lesion is slowly progressive, such as a tumour, symptoms of cerebellar deficiency are much less severe than when it is acute, and considerable recovery from the effects of an acute lesion can always be anticipated. These facts seem to imply that other parts of the nervous system can to a considerable extent compensate for loss of cerebellar function.

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6. THE VISUAL FIBRES AND THE VISUAL FIELDS

The Visual Fields

Investigation of the extent of the fields of vision and of the degree of visual acuity within them plays an important part in the routine examination of patients suffering from nervous diseases. 'Perimetry' is the term applied to the mapping of the visual fields. This may be carried out in the following ways:

(1) Confrontation Perimetry.

This method is extremely rough and only gross defects of the visual fields are likely to be detected by it. The observer stands opposite to the patient and about a yard away from him. The patient is instructed to cover one eye with his hand and to fix the gaze of his other eye upon the opposite eye of the observer. The observer then brings a test object, usually his finger, inwards from beyond the periphery of his own visual field, midway between himself and the patient, who is asked to say when he first sees it. This procedure is carried out above, below, and to either side and, if necessary, intermediately, and the observer is able to determine the extent of the patient's visual field relative to his own. Besides ascertaining the outer boundaries of the visual field by the method described, the test object should be made to traverse the field in various directions and the patient should be asked to state if it disappears from view and when it reappears. In this way a scotoma or an area of defective vision within the field may be detected.

In young children and unco-operative patients a field defect may sometimes be detected by observing whether the patient notices an object brought in from the periphery in various directions, or whether he blinks in response to a feint with the hand towards the eye—the menace reflex.

(2) Mechanical Perimetry.

There are a large number of perimeters in use by which the visual fields can be tested and recorded. The patient is made to gaze at a fixation point and the test object is then moved in the arc of a circle towards the fixation point. The test object is at a distance from 250 to 330 mm. from the eye and is usually between 3 and 10 mm. in diameter. The visual acuity differs in different parts of the visual field. Although a moving object is readily perceived in the peripheral part, central vision for a stationary object is more acute than peripheral vision. Hence the smaller the test object the smaller the visual field in which it is perceptible. The severity of the test is indicated by the fraction $\dfrac{\text{diameter of object}}{\text{distance}}$. If a 3 mm. test object is used at a distance of 330 mm., this fraction is 3/330. Boundaries of the normal visual field for 3/330 are situated at about 60° up, 60° in, 75° down, and 100°, or a little more, out. The field for colours is smaller than that for white, that for blue and yellow being somewhat larger than that for red and green.

(3) Perimetry by Bjerrum's Screen.

A mechanical perimeter is a useful method for determining the boundaries of the visual fields. More refined methods, however, are often necessary for investigating the central portions. Bjerrum's screen enables test objects of 1 and 2 mm. to be used at a distance of 2 metres—1/2000 and 2/2000. In this way very slight defects of visual acuity may be detected and, since they are projected upon a large area, accurately mapped. A depression of visual acuity in the centre of the field may not be demonstrable by tests such as reading types. It is for the detection of such defects that Bjerrum's screen is of special value. The normal field for a 1/2000 test object by this method extends to nearly 26° in all directions. If a defect exists to 1/2000 or 2/2000 objects, larger objects should be used until one is seen in the area of impaired vision.

The term 'hemianopia' indicates a loss of vision in half of the visual field. When this is present in the same half of both fields, for example both right halves, we speak of 'homonymous hemianopia'. When the field defect on one side is a mirror image of that on the other, the hemianopia is said to be bitemporal or binasal, according to the halves affected. A field defect limited to one quadrant is described as 'quadrantic hemianopia' or 'quadrantanopia'. When homonymous field defects are capable of being accurately superimposed one upon another, they are said to be congruous, when their corresponding boundaries differ, they are said to be incongruous.

Closely related disturbances of visual function are—visual inattention, indicated by a failure to notice movement of an object such as the observer's finger in one half field, especially when there is a competing stimulus in the opposite half field, and visual disorientation, which is inability to localize objects seen, especially to estimate relative distance.

THE PATH OF THE VISUAL FIBRES

From the Retina to the Primary Visual Centres

The Optic Nerves.

The fibres of the optic nerve are the axones of the ganglion cells of the retina The macula is the region of most acute vision, and ocular fixation is so regulated as to bring on to the macula the image of any object at which we look. The macular fibres are thus the most important part of the visual afferent system. In the retina these fibres run from the macula to the temporal side of the optic disk or papilla Fibres from the upper and lower temporal quadrants of the retina are displaced by the macular fibres to the upper and lower parts of the disk, and fibres from the nasal quadrants occupy the nasal side. The optic nerves pass backwards and inwards through the optic foramina and terminate posteriorly at the optic chiasma.

The Optic Chiasma.

At the optic chiasma the two optic nerves unite and decussation of the fibres derived from the nasal halves of the retinae occurs (Fig. 7). The position of the chiasma is a variable one and assumes importance in relationship to the field defects produced by its compression by tumours in this region. It is usually situated a little behind the tuberculum sellae It is rarely as far forward as the sulcus chiasmatis and is sometimes much farther back behind the dorsum sellae and is then related to the posterior part of the pituitary. The relationship of the chiasma to the sella turcica, pituitary body, and infundibulum is thus variable. The most important of its other relations are, above, the floor of the third ventricle and, laterally, the internal carotid artery.

The decussating fibres from the nasal half of each retina expand within the chiasma, those from the anterior part of the optic nerve passing inwards and forwards to form a loop, entering the base of the opposite optic nerve before passing backwards to the opposite optic tract, where they are joined by the nasal fibres from the posterior part of the nerve which cross the chiasma more posteriorly. The fibres from the temporal halves of the retinae do not decussate, but are continued backwards on the same side in the optic tract.

The Optic Tract.

Each optic tract is thus composed of fibres from the temporal half of the retina of the same side and from the nasal half of the retina of the opposite side. Within the tract the uncrossed fibres lie dorso-laterally and the crossed fibres ventro-mesially. Each optic tract sweeps outwards and backwards between the cerebral peduncle and the gyrus hippocampi, and finally inwards to terminate in the superior corpus quadrigeminum, the external geniculate body, and the pulvinar of the optic thalamus, but experimental evidence throws doubt upon whether the last structure plays any part either in vision or in the optical reflexes. The external geniculate body appears to receive the fibres concerned in visual perception, and the superior corpus quadrigeminum those destined to excite reflex activity. Besides the localization in a lateral plane already described, there is in the optic

Fig. 7   Diagram of the Central Connexions of the Optic Nerve and Optic Tract.
(Cunningham, Text book of Anatomy)

nerves, chiasma, and tracts a considerable degree of localization of the fibres in the vertical plane also, fibres from the lower halves of the retinae lying below, and those from the upper halves above.

Visual Field Defects due to Lesions of the Optic Nerves, Chiasma, and Tracts

We are now in a position to apply the anatomical facts just described to the interpretation of the visual field defects produced by lesions of the optic nerves, chiasma, and tracts.

(1) Lesions of the Optic Nerve.

A lesion of one optic nerve produces a field defect limited to the same eye, since it lies anterior to the chiasmal decussation. The type of field defect produced varies according to the pathological nature of the lesion and is more fully discussed in a later chapter. In general, inflammatory and compressive lesions of the optic nerve are likely to lead to a central scotoma or to a sector defect of irregular shape, but in papilloedema due to increased intracranial pressure the characteristic field defect is an enlargement of the blind spot, together with a peripheral concentric constriction.

(2) Lesions of the Chiasma.

The commonest lesions of the optic chiasma are those due to pressure, either by tumours arising in the pituitary body or above the sella turcica, such as suprasellar cysts and meningiomas. In addition the chiasma itself may be the site of a gliomatous tumour, or may be compressed by a tumour arising in the third ventricle, by distension of the third ventricle in hydrocephalus, or by an intracranial aneurysm. It may be involved in local chronic arachnoiditis, or in syphilitic meningitis, in demyelinating disorders such as disseminated sclerosis and neuromyelitis optica, and, rarely in vascular lesions and after head injury.

When the point of maximal pressure is in the middle line the decussating fibres are first compressed, with the result that at some stage in the development of the growth there is bitemporal hemianopia, for, as we have seen, the decussating fibres are derived from the nasal halves of both retinae, and owing to the refractive effect of the optic lens these parts of the retinae receive images from the temporal halves of the visual fields. When pressure is exerted upon the chiasma from below, the fibres from the lower nasal quadrants of the retinae are first affected. Hence the field defect begins in the upper temporal quadrants When the pressure comes from above, the reverse is the case. This rather schematic explanation must now be qualified by the statement that pituitary and suprasellar tumours rarely exert a symmetrical pressure in the middle line. Hence the decussating fibres are usually involved on one side before the other. Consequently, in the case of pituitary tumours, the field defect begins as a rule in the upper temporal quadrant on one side as an indentation which may be associated with a paracentral scotoma with which it subsequently fuses. It then spreads to the lower quadrant, while a similar change occurs a little later on the opposite side (Fig. 8). Further pressure leads to involvement of the nasal field of the eye first affected and at this stage there is blindness of one eye with temporal hemianopia of the other. Finally the remaining nasal field is lost.

Owing to the complicated paths of the fibres in the chiasma and the liability of pressure to involve also either the optic nerve or tract, many forms of visual field change are encountered.
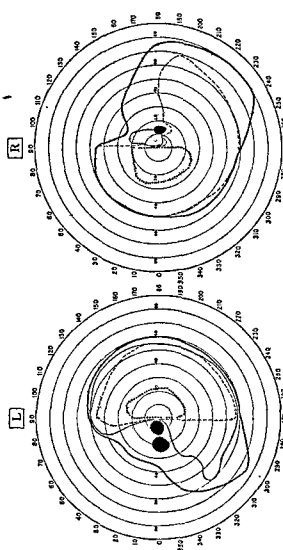
FIG. 8. Bitemporal Hemianopia. Typical fields in a moderately advanced case of Pituitary Tumour without Acromegaly. Duration one year.

Objects $\frac{1}{10}$, $\frac{5}{10}$, $\frac{10}{10}$, $\frac{15}{10}$, $\frac{20}{10}$, $\frac{25}{10}$ red.
R.V. $\frac{6}{5}$, L.V. $\frac{6}{5}$.

(Traquair *An Introduction to Clinical Perimetry*, 2nd Edition)

Rarely compression of the lateral angles of the chiasma may occur, for example, in cases of severe atheroma of the internal carotid arteries. Since the non-decussating fibres are affected the resulting field defect is binasal hemianopia.

The most characteristic feature of the visual field defects associated

with lesions of the chiasma is their asymmetry compared with the more symmetrical character of the defects due to lesions of the optic tracts and radiation.

(3) Lesions of the Optic Tract.

Since the optic tracts are composed of fibres from the temporal half of the retina of the same side and the nasal half of the opposite retina, they carry impulses derived from visual images of objects in the opposite half of the visual field. Lesions of one optic tract, therefore, result in a crossed homonymous field defect which usually begins in one quadrant and rarely extends to a complete homonymous hemianopia The defects in the two visual fields are not as a rule congruous, the visual field defect being usually slightly greater upon the side of the lesion than upon the opposite side. A homonymous field defect occurs in cases of pituitary tumour about half as frequently as bitemporal hemianopia, and the optic tract may also be compressed by other tumours at the base of the brain, including the anterior part of the temporal lobe and by aneurysm of the posterior communicating artery, and may be involved in inflammatory lesions, such as basal syphilitic meningitis. .

THE GENICULO-CALCARINE PATHWAY

The last stage of the path of the visual fibres to the cortex begins at the external geniculate body. From this they enter the posterior limb of the internal capsule, where they lie behind the sensory fibres and internal to the fibres of the auditory radiation. They emerge from the capsule as the optic radiation, or geniculo-calcarine path, which runs to the area striata of the occipital lobe. This path varies in directness for different fibres. The more dorsal fibres pass directly to the visual cortex, but those situated more ventrally in the optic radiation turn downwards and forwards into the uncinate region of the temporal lobe, and there spread out over the tip of the descending horn of the lateral ventricle before turning back along the inferior aspect of the ventricle to reach the inferior lip of the calcarine fissure. As we have seen, fibres derived from the lower half of the retina remain below those from the upper half throughout the optic chiasma and tracts, and this relationship persists in the geniculo-calcarine pathway. Hence the more direct upper fibres of the optic radiation are derived from the upper halves of the retinae and are excited by images from the lower halves of the visual fields, and the reverse is true of the lower fibres, which pass by way of the tip of the temporal lobe. These facts explain the nature of the visual field defects produced by lesions involving the optic radiation in the temporal and parietal lobes respectively. A left temporo-sphenoidal abscess, for

example, tends to damage the lower fibres rather than the upper, and the resulting field defect lies in the upper half of the visual fields Since

(Traquair, *An Introduction to Clinical Perimetry*, 2nd Edition)
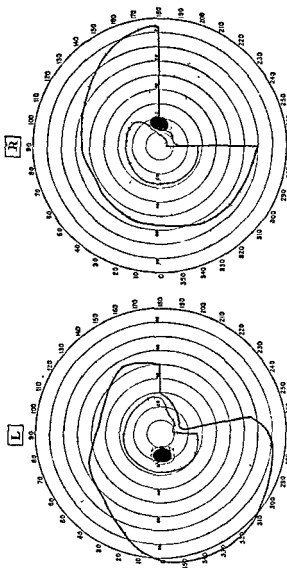
FIG. 9. Right Lower Quadrantic Hemianopia due to Tumour (Meningoma) involving Posterior Temporal and Lower Parietal Areas of left side, compressing the Optic Radiations.

Objects $\frac{3}{330}$° $\frac{5}{330}$° $\frac{3}{1000}$° blind spot $\frac{5}{330}$°.

V.R. and L. 6/9ths plus.

a unilateral lesion involves only the fibres concerned in vision in the opposite half-fields, the field defect is a crossed homonymous superior quadrantic one. Conversely a lesion involving the optic radiation in the parietal lobe may affect only the upper fibres and produce a crossed inferior quadrantic loss (Fig. 9). Complete destruction of one optic

radiation produces a crossed homonymous hemianopia (Fig. 10). Homonymous field defects due to lesions of the optic radiation are
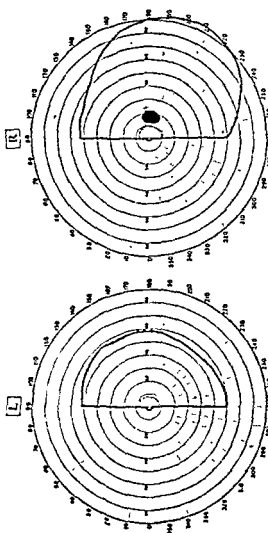
FIG. 10. Homonymous Hemianopia from Glioma of the Right Parietal Lobe. Male, aged 50. (Bean-cut Hemianopia with sparing of Fixation Area for 3½° and for 10/10. Depression of 10/2 Field. Blind spot enlarged. R.V. and L.V. 6/6ths.

(*Traquair, An Introduction to Clinical Perimetry, 2nd Edition*)

congruous with escape of a small area around the fixation point—'sparing of the macula'. The commonest lesions involving the optic radiation are vascular lesions and tumours. The lower fibres may be involved in abscess of the temporo-sphenoidal lobe. The radiations are early affected by degeneration in diffuse sclerosis (Schilder's disease).

' THE VISUAL CORTEX

The cortical visual area or 'area striata' is situated above and below the calcarine fissure and in adjacent portions of the cuneus and lingual gyrus, and sometimes extends slightly on to the lateral surface of the occipital pole (frontispiece). From what has been said concerning the representation of the retinae in the optic tracts, it will be realized that the visual cortex on one side receives impulses from the temporal half of the retina on the same side and the nasal half of the opposite retina, that is, those halves of the retinae which are excited by images derived from the opposite halves of the visual fields. The macula is not bilaterally represented at the cortex, but each half is represented in the opposite visual cortex. The retinae may be regarded as projected upon the visual cortex as follows. The macula occupies a wedge-shaped area of the most posterior part of the visual cortex, extending slightly on to the lateral surface of the occipital lobe, the apex of the wedge being 2 or 3 cm. anterior to the occipital pole. The periphery of the retina is represented in front of the macular area of the cortex, concentric zones of the retina from the macula to the periphery being probably represented from behind forwards in the visual area. The upper quadrants of the retina are represented in the upper part of the visual cortex, above the calcarine fissure, and the lower quadrants below. From these facts the effects of lesions involving the visual cortex can readily be understood. Lesions of one visual cortex cause crossed homonymous field defects. Lesions involving the upper halves, i.e. the areas above the calcarine fissure produce inferior quadrantic field defects, and vice versa. Lesions confined to the occipital pole produce central or paracentral scotomas. Lesions more anteriorly placed tend to produce scotomas involving the periphery of the visual fields, with escape of the central portions, provided the macular fibres of the optic radiation are not injured at the same time. Complete destruction of the visual cortex on one side produces a crossed homonymous hemianopia.

The main arterial supply of the visual cortex is the posterior cerebral artery, though there is reason to believe that the macular area is also supplied by the middle cerebral. Thrombosis of the posterior cerebral artery therefore causes a crossed homonymous hemianopia, with, as a rule, escape of the fixation point. Bilateral thrombosis of the posterior cerebral arteries causes complete blindness, except for a small area around the fixation points. The commonest lesions of the visual cortex are vascular lesions and tumours. Many cases of gun-shot wound of this part of the brain were observed during the 1914 war.

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7. THE OCULAR MOVEMENTS

The ocular movements are described as horizontal movement outwards, or abduction; horizontal movement inwards, or adduction; vertical movement upwards, or elevation; vertical movement

downwards, or depression. The eye is of course capable of diagonal movements at any intermediate angle. The term 'rotation' should be reserved for wheel-like movements around an imaginary pivot passing from before backwards through the centre of the pupil. Such movements of rotation do not normally occur, but are only observed as a result of the unbalanced action of certain muscles. Inward rotation is a movement similar to that of a wheel rolling towards
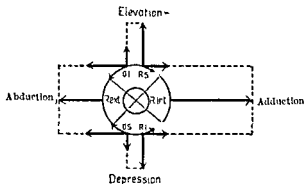
Fig. 11. Scheme to illustrate the action of the Ocular Muscles.

(*The Lancet*, after Marquez, from Fuchs)

the nose, and outward rotation is the opposite rotatory movement. Normally the movements of the two eyes are harmoniously symmetrical and we then speak of conjugate ocular movements or deviation. Conjugate ocular deviation is described as horizontal or lateral, upward and downward. Conjugate adduction of the two eyes is known as convergence.

THE EXTRINSIC OCULAR MUSCLES

The extrinsic ocular muscles are the four recti, superior and inferior, external and internal, and the two obliques, superior and inferior. The action of each of these muscles is shown in the following table and in the diagram (Fig. 11), in which the relative power of the muscles in different directions is indicated by the length of the arrows.

Superior rectus	Internal rectus	Inferior rectus	Inferior oblique	External rectus	Superior oblique
Adductor	Adductor	Adductor	Elevator	..	Depressor
Internal rotator	..	External rotator	External rotator	..	Internal rotator
Elevator	..	Depressor	Abductor	Abductor	Abductor

It will be seen that only the external and internal recti act in a single plane. The other muscles always act in concert with each other in such a way that their conflicting tendencies cancel and a harmonious resultant is produced. Thus when the two obliques aid the external rectus in abduction their vertical and rotatory forces cancel each other; and when the superior rectus and inferior oblique contract together in elevating the eye their horizontal and rotatory components also cancel. In conjugate deviation there is a harmonious contraction of the appropriate muscles of the two eyes. In lateral conjugate deviation the external rectus of one eye and the internal rectus of the other are associated; in conjugate deviation upwards and downwards, the elevators and depressors of the two eyes respectively; and in convergence, the internal recti. Ocular movements must not be regarded as consisting merely of contractions of the prime movers, the muscles actively displacing the eye. There is evidence that graded contraction and relaxation of their antagonists play an important part in orderly movement.

PARALYSIS OF INDIVIDUAL OCULAR MUSCLES

The more important results of paralysis of an ocular muscle are (1) defective ocular movement, (2) squint, (3) erroneous projection of the visual field, and (4) diplopia.

(1) Defective Ocular Movement.

Defective ocular movement is demonstrated by asking the patient to fix his gaze on an object, such as the observer's finger, which is then moved upwards and downwards and to either side, convergence being tested by bringing it towards the patient. The movement is defective in the direction in which the eye is normally moved by the muscle which is paralysed Slight weakness of a muscle, especially of one of the elevators or depressors, may not lead to any defect of ocular movement evident to the observer.

(2) Squint.

Squint, or strabismus, is the term applied to a lack of parallelism of the ocular axes It is necessary to distinguish paralytic squint from concomitant or spasmodic squint. Paralytic squint may be present when the eyes are at rest, in which case it is due to the unbalanced action of the normal antagonist of the paralysed muscle, for example, the affected eye may be slightly adducted when the external rectus is paralysed. More often it is only apparent when the eyes are deviated in the direction in which the eye should be pulled by the paralysed muscle, or if squint is present at rest it is increased by

such a movement. Concomitant squint, however, is present at rest and is equal for all positions of the eyes, and, if the fixing eye *is* covered, the movements of the squinting eye are found to be full. Concomitant squint is not associated with diplopia; paralytic squint, at least in the early stages, usually is.

When the external rectus is paralysed the ocular axes converge and the squint is said to be convergent. Paralysis of the internal rectus causes divergent squint. Divergent squint, however, also accompanies myopia, and is often present in an unconscious patient without indicating paralysis of an ocular muscle. The deviation of the axis of the affected eye from parallelism with that of the normal eye is called the 'primary deviation'. If the patient is made to fix an *object in a direction requiring the action of the affected muscle and* at the same time is prevented from seeing it with his normal eye, the latter is found to deviate too far in the required direction. This is called 'secondary deviation', and is due to the increased effort evoked by his attempt to move the affected eye.

(3) Erroneous Projection of the Visual Field.

Afferent impulses from the proprioceptors of the ocular muscles convey information which is of importance in our perception of space. If we look at a candle straight in front of us and then, turning the eyes but not the head, at a candle placed to one side, in each case the image of the candle falls upon the macula. The difference for consciousness between 'straight in front' and 'to one side' depends upon the only variables in the afferent stream of impulses, namely, those derived from the ocular muscles. In the former case these are at rest, in the latter one conjugate pair is contracted and their antagonists are relaxed. Let us now consider what happens when the right external rectus is paralysed. On conjugate deviation to the right the left eye moves normally and the right eye remains directed forwards *The image of the object regarded falls in the left eye upon* the macula, in the right eye upon the nasal half of the retina. Proprioceptor impulses from the ocular muscles convey to the patient the information that he is looking to the right, and he is accustomed to regard an *object, the image of which falls upon the* nasal half of the right retina, as situated to the right of one of which the image falls upon the macula. Consequently he sees two images and projects the false image perceived by his affected eye to the right of the true image perceived by his normal eye. If now his normal eye be covered and he be asked to touch the object he will direct his finger to the right of its true position. The erroneous projection is always in the normal direction of action of the affected muscle. When it produces sufficient spatial disorientation vertigo results.

F

(4) Diplopia.

Erroneous projection of the visual field of the affected eye is responsible for double vision. Since both eyes are used two images are seen, one correctly and one erroneously projected, the true and the false image. Let us apply our previous illustration to the interpretation of diplopia.

In paralysis of the right external rectus the right eye is not abducted If the patient attempts to deviate his eyes horizontally to the right, the image of a small object falls in the left eye upon the macula. In the right eye, which is not displaced, it falls upon the nasal half of the retina, hence it is seen in (or projected into) the temporal field of the right eye. The false image is thus parallel with and to the right of the true image. The farther the test object is moved to the right the farther into the nasal half of the right retina its image moves, and the farther the false image appears to move to the right From these facts can be deduced two simple rules governing the appearance of diplopia:

(1) The separation of the images increases the farther the eyes are moved in the normal direction of pull of the paralysed muscle

(2) The false image is displaced in the direction of the plane or planes of action of the paralysed muscle.

It follows from the two rules that when the gaze is so directed that the separation of the images is greatest, the more peripherally situated image is the false one, derived from the affected eye, which can thus be ascertained. The simplest method is to cover up one eye with a red glass The patient is then made to look at a light, such as an ophthalmoscope lamp, or a small but well-illuminated piece of white paper. This is moved until the maximal separation of the images is obtained, and they are then distinguishable by their colour. If coloured glass is not available, an intelligent and co-operative patient is usually able to distinguish the images by noticing which disappears when each eye is covered separately.

When the affected eye has been discovered, the paralysed muscle can be determined It is the muscle which normally displaces the eye in the direction of displacement of the false image. The positions of the false images resulting from paralysis of the various ocular muscles are described below for the right eye. The description will apply to the left eye if right be substituted for left and vice versa. The diplopia is said to be 'simple', or uncrossed, when the false image lies on the same side of the true image as the affected eye, and 'crossed' when it lies on the opposite side.

Position of False Image in Paralysis of the Ocular Muscles of the Right Eye.

External Rectus. The diplopia is uncrossed and the maximal separation of the images occurs on abduction when the false image is level with, and parallel with, the true.

Internal Rectus. The diplopia is crossed and the maximal separation of the images occurs on adduction when the false image is level with, and parallel with, the true.

Superior Rectus. The false image is above and to the left of the true and tilted away from it. Vertical separation of the images is greatest on abduction, the tilting greatest on adduction. The diplopia is crossed.

Inferior Rectus. The false image is below and to the left of the true and tilted towards it. Vertical separation of the images is greatest on abduction, and tilting on adduction. The diplopia is crossed.

Inferior Oblique. The false image is above and to the right of the true and tilted away from it. The diplopia is uncrossed. Vertical separation of the images is greatest on adduction, and tilting on abduction.

Superior Oblique. The false image is below and to the right of the true and tilted towards it. The diplopia is uncrossed. Vertical separation of the images is greatest on adduction, and tilting on abduction. Since the diplopia occurs on looking downwards it is particularly troublesome to the patient when walking downstairs.

A patient suffering from diplopia usually rotates or tilts the head into the position in which the least demand is made upon the paralysed muscle.

THE NUCLEI OF THE OCULAR MUSCLES

The lower motor neurones which innervate the ocular muscles originate in the nuclei of the third, fourth, and sixth cranial nerves. The first two lie in the midbrain just anterior to the aqueduct of Sylvius at the level of the superior and inferior corpora quadrigemina. The nuclei of the sixth nerve lie in the pons beneath the *floor of the upper part of the fourth ventricle and partly encircled* by the fibres of the seventh nerves.

The precise representation of muscles in the nucleus of the third *nerve* is still somewhat uncertain, but the diagram (Fig 12) represents the probable arrangement. The median, unpaired, small-celled nucleus of Perlia is the centre for convergence and accommodation, while the lateral, paired, small-celled nucleus of Edinger-Westphal innervates the constrictor of the pupil. The remainder of the nucleus

is the paired, large-celled, lateral nucleus in which the muscles are represented from above downwards as follows: levator palpebrae, superior rectus, inferior oblique, internal rectus, inferior rectus. Decussating fibres unite the lower parts of the nuclei. Immediately below the third nerve nucleus lies that of the fourth nerve which innervates the opposite superior oblique. This nucleus and the adjacent lowest part of the third nerve nucleus innervate the two

FIG. 12 Diagram of the Oculo-
motor Nucleus

(From Cunningham's *Text book of Anatomy*,
after *Perlia*)

muscles concerned in depression of the eye, and the two elevating muscles are innervated by mutually adjacent portions of the upper half of the third nerve nucleus.

THE SUPRANUCLEAR AND INTER-NUCLEAR PATHS FOR OCULAR MOVEMENT

Conjugate Lateral Deviation.

Movements of the eyes can be evoked from two areas of the cerebral cortex by electrical stimulation. One supranuclear path of the motor fibres concerned in conjugate lateral deviation begins in the posterior part of the second frontal convolution, anterior to the pre-central gyrus. Electrical stimulation of this area produces deviation of the eyes to the opposite side. From the second frontal convolution the supranuclear path runs through the corona radiata to the internal capsule, where it is situated near the genu, and then to the cerebral peduncle. In the midbrain the fibres decussate and pass downwards into the upper part of the pons. Just above the sixth nucleus the path divides, some fibres running into that nucleus, while others cross the middle line, turn upwards in the posterior longitudinal bundle, and terminate in that part of the third nerve nucleus which innervates the opposite internal rectus. Thus excitation of the supranuclear fibres causes a contraction of the opposite external rectus and the ipsilateral internal rectus, and so produces conjugate ocular deviation to the opposite side.

The other cortical area for eye movements is in or near the visual cortex in the occipital lobe. From here fibres have been traced through the pulvinar to the midbrain.

Conjugate Vertical Deviation.

Less is known about the supranuclear paths for conjugate vertical than about those for conjugate lateral deviation. Probably they also originate in the second frontal convolution, but on electrical excitation of this region the more powerful lateral movement of the eyes overpowers the vertical movements. The fibres probably run through the internal capsule and decussate in the upper part of the midbrain. Those concerned in conjugate elevation appear to cross at a higher level than those concerned in conjugate depression. Collier suggests that the former decussate in the posterior commissure. After decussating they terminate in the appropriate regions of the third nerve nucleus and in the fourth nerve nucleus.

Conjugate Convergence.

The supranuclear paths for conjugate convergence are also incompletely known. Since convergence is normally the response to the perception or imagination of a visual image, the path of excitation probably runs through the visual cortex, and then, possibly passing through the second frontal convolution, by a descending route with the pyramidal fibres to the midbrain, to terminate after decussation in the nuclei of the internal recti.

Reflex Ocular Fixation.

In voluntary ocular deviation the patient turns the eyes spontaneously or in response to a command. In addition, conjugate ocular deviation may be excited by various stimuli.

1. *Retinal Stimulation.* The retinal stimulus may be either (a) macular, or (b) peripheral.

(a) The patient's head is kept motionless and he is told to fix his gaze upon an object which is then moved in various directions. Appropriate conjugate ocular deviation occurs to keep the image of the object upon the macula.

(b) It is an everyday experience that a moving object in the periphery of the visual field excites deviation of the head and eyes so directed that its image is brought upon the macula.

2. *Auditory Stimulation.* In response to a sound the eyes are deviated in the direction from which the sound appears to come.

3. *Labyrinthine Stimulation.* Caloric, rotatory, and electrical excitation of the labyrinth evokes conjugate ocular deviation (see p. 180).

4. *Passive Movement of the Head.* The patient is made to fix an object with his gaze and the head is then rotated, flexed, or extended at the neck. Afferent impulses from the cervical spine

excite appropriate ocular deviation to keep the image of the object on the macula, whatever the position of the head. For example, if the head is passively rotated to the left, the eyes become deviated to the right.

The regions concerned in ocular fixation are the visual cortex and the descending path to the midbrain via the pulvinar and the posterior longitudinal bundle.

The Posterior Longitudinal Bundle.

The posterior longitudinal bundle is an important path linking the oculomotor nuclei By it the external rectus is associated with the opposite internal rectus in conjugate lateral deviation, and it carries impulses concerned in the reflex ocular movements described in the last section.

Anteriorly it can be traced into the subthalamic region, where it receives fibres from the nucleus of Darkschewitsch and the inter-stitial nucleus of Cajal, the former bringing it into relation with the posterior commissure. Passing through the midbrain it unites the third, fourth, and sixth nuclei, and at the level of the last-named it receives an important contribution from Deiters' nucleus. In the pons also fibres probably enter the bundle from the fifth nerve and from the auditory component of the eighth, and it descends through the medulla, where it sends fibres to the spinal accessory nucleus, to form part of the anterior column of the spinal cord.

It thus links together the auditory and vestibular nerves with the oculomotor nuclei and the muscles which rotate the head.

SUPRANUCLEAR AND INTERNUCLEAR LESIONS

Dissociation of Voluntary Ocular Movement and Reflex Fixation. Bilateral lesions of the frontal centres or their descending paths interfere with voluntary movement of the eyes which, however, can still follow a slowly moving object, or fix an object while the head is moved In such cases reflex fixation is overactive and the eyes tend to remain fixed on an object until the gaze is obscured. The converse condition, a lesion interfering with reflex fixation, makes it impossible for the subject to fix and hence to see clearly a moving object or an object when he himself is moving. (Holmes, 1938.)

Conjugate Lateral Movement.

We may encounter either spasm, paralysis, or dissociation of conjugate lateral movement of the eyes.

Spasm of Conjugate Lateral Movement may occur as an element in a Jacksonian epileptic attack, of which it may be the first symptom when the exciting lesion is situated in the second frontal convolution,

the eyes being deviated to the opposite side. It may occur in convulsions excited by an occipital lesion, in which case there is usually a visual aura. It is commonly observed also in the generalized convulsions of epilepsy Spasmodic lateral deviation occasionally occurs in Parkinsonism due to encephalitis lethargica, though in this condition vertical deviation is more frequent. It may be excited reflexly by a lesion of the labyrinth, the eyes in this case being usually deviated towards the lesion. In paralysis of conjugate lateral movement in an unconscious patient the eyes are often deviated to the non-paralysed side by the unbalanced action of the normal hemisphere.

Paralysis of Conjugate Lateral Movement to one side may occur as a result of a lesion of the supranuclear fibres at any point in their course, but the effects of a unilateral lesion above the pons are always transitory. When the lesion is situated above the decussation of these fibres in the lower midbrain lateral movement to the opposite side is paralysed. When the lesion is below the decussation, i e. in the pons just above the sixth nucleus, the paralysis is to the same side as the lesion. A lesion involving the decussation leads to bilateral paralysis, and this may also occur as a result of one extending to both sides of the pons. It must be remembered that the supranuclear fibres are concerned with voluntary movement of the eyes, and the true test of their conductivity is to tell the patient to look to one or the other side. To ask him to follow a moving finger with his gaze is to introduce a reflex element into the response It is common to find in a patient, unconscious from a haemorrhage into the internal capsule, evidence of a paralysis of conjugate ocular deviation which apparently quickly disappears when he recovers consciousness. Such patients, however, often show slowness or weakness in deviating the eyes to the opposite side on command, though they are able to follow with their eyes a moving object.

A pontine lesion usually abolishes reflex conjugate lateral deviation as well as the voluntary movement—a point in favour of the existence in this region of a 'centre', from which starts a final common path shared by both voluntary and reflex movements.

In paralysis of conjugate lateral deviation the affected internal rectus contracts normally on convergence unless the supranuclear path for convergence, which is separate from that for lateral deviation, should also be involved. This is an example of the rule that supranuclear lesions cause paralysis of movements and not of muscles.

Dissociation of Conjugate Lateral Movement. Dissociation of conjugate lateral movement occurs when either the external or the internal rectus contracts more strongly than its conjugate fellow, and

the normal harmony of the two eyes is disturbed. Most commonly the external rectus contracts normally, but the opposite internal rectus is weak or paralysed for conjugate lateral movement but contracts normally on convergence. In this case the lesion involves the ascending fibres of the posterior longitudinal bundle linking the two muscles together, but the supranuclear path for convergence which terminates at a higher level escapes (ophthalmoplegia internuclearis anterior of Lhermitte). A lesion involving the nucleus of the internal rectus muscle in the third nerve nucleus, or the fibres running to this muscle in the third nerve, of course paralyses the muscle both for conjugate lateral movement and for convergence. A lesion of the sixth nerve or its nucleus causes paralysis of the external rectus, but the opposite internal rectus contracts normally on conjugate lateral deviation and on convergence.

Causes of Conjugate Lateral Paralysis

The commonest cause of conjugate lateral paralysis is tumour involving the pontine centre. It may also be produced by encephalitis lethargica, though less often than vertical paralysis, and by disseminated sclerosis, in which disease dissociation of lateral movement is common, the internal rectus contracting less strongly than the external. Vascular lesions account for most of the remaining cases.

Conjugate Vertical Movements.

Spasm of Vertical Conjugate Movement upwards may occur in an epileptic fit or in an attack of petit mal. It is also the commonest form of oculogyral spasm found in encephalitic Parkinsonism, though downward and lateral spasm occasionally occur. Upward deviation of the eyes also occurs normally during sleep, and on voluntary closure of the eyelids and blinking.

Paralysis of Vertical Conjugate Movement seems not to occur as a result of lesions above the midbrain. At the level of the superior corpora quadrigemina there exist supranuclear mechanisms for the conjugate vertical movements and for convergence, since any of these movements may be abolished separately and without evidence of a nuclear lesion. Moreover, as in the case of conjugate lateral deviation, voluntary vertical deviation may be lost while the movement can still be excited reflexly, for example by flexing or extending the head when the patient's gaze is fixed upon a motionless object. Such a loss of voluntary with retention of reflex movement indicates a lesion of the supranuclear path, while the final common path from the hypothetical midbrain 'centre' remains intact. The centre for vertical movement upwards is situated at a higher level in the mid-

brain than that for downward movement, since a tumour arising in the third ventricle and impinging upon the midbrain from above impairs the former before the latter. Upward deviation is much more frequently lost than downward deviation, and, as Collier has pointed out, its loss is sometimes associated with retraction of the upper lids. In some cases the defect is congenital. It may result from encephalitis lethargica, neoplasm of the third ventricle, midbrain or pineal body, vascular and other lesions of the upper midbrain.

Paralysis of Convergence.

Paralysis of convergence is rarely observed as a result of lesions of the cerebral hemispheres, probably because its supranuclear paths are bilateral. It is common, however, in extrapyramidal syndromes associated with rigidity, especially in Parkinsonism due to encephalitis lethargica. It is also met with as a result of lesions involving the convergence centre in the midbrain and may occur after head injury. In such cases there may be an isolated loss of convergence and accommodation. More often loss of convergence is associated with loss of vertical conjugate movement, and sometimes with loss of the reaction of the pupils to light. Loss of convergence is occasionally, and spasm of convergence usually, hysterical.

NUCLEAR OPHTHALMOPLEGIA

By nuclear ophthalmoplegia is meant a paralysis of ocular muscles due to a lesion involving the nuclei of the oculomotor nerves. When the extrinsic ocular muscles are involved the term external ophthalmoplegia is used: paralysis of the pupillary and ciliary muscles is known as internal ophthalmoplegia. When both are affected together we speak of total ophthalmoplegia. Internal ophthalmoplegia is dealt with in a later section. We are here concerned only with external ophthalmoplegia, including ptosis.

Nuclear ophthalmoplegia must be distinguished from supranuclear lesions and from lesions of the oculomotor nerve-trunks. As we have seen, supranuclear lesions cause disturbances of conjugate ocular movement. Consequently the ocular axes remain parallel and diplopia is not produced. Nuclear lesions may be unilateral, but are more often bilateral. When bilateral they are not symmetrical, and loss of parallelism of the ocular axes and diplopia occur. The varied degree of paralysis of the muscles of both eyes, with or without internal ophthalmoplegia, rarely simulates a lesion of the third nerve-trunks, in which as a rule the muscles innervated by the nerve are all affected to an equal extent. Nuclear ophthalmoplegia confined to the fourth nerve has probably never been verified. Since the sixth

nerve supplies only one muscle, an isolated lesion of the sixth nerve nucleus can only be distinguished from a lesion of the nerve-trunk by the presence of associated symptoms of a lesion of the pons.

The following are the principal causes of nuclear ophthalmoplegia:

(1) *Massive Lesions involving the Brain-stem*, especially tumours of the third ventricle, midbrain, pineal body and pons, and vascular lesions

(2) *Intoxications* Alcohol was held responsible by Wernicke for the condition he described as acute superior haemorrhagic polio-encephalitis, but this has recently been ascribed to vitamin B deficiency (Campbell and Biggart, 1939). It is characterized by a rapidly progressive ophthalmoplegia, often with pupillary paralysis and ptosis, with bulbar symptoms, ataxic gait, weakness and loss of tendon reflexes in the limbs, somnolence or delirium, often proving fatal in from ten to fourteen days. Autopsy shows haemorrhages in the grey matter of the floor of the aqueduct of Sylvius.

Lead-poisoning occasionally causes nuclear ophthalmoplegia.

(3) *Toxi-infective States* In this group fall syphilis, encephalitis lethargica, disseminated sclerosis, and acute disseminated encephalomyelitis. Syphilitic nuclear ophthalmoplegia may be vascular in origin, but a degenerative type occurs in tabes and in general paralysis.

(4) *Progressive Muscular Atrophy* involves the oculomotor nuclei very rarely.

(5) *Syringomyelia* also rarely produces ophthalmoplegia.

(6) *Head injury* is a rare cause of nuclear ophthalmoplegia, which may result from contusion of the brain-stem.

(7) *Congenital Defects* of ocular movement occur. These may be hereditary and associated with other hereditary abnormalities.

NYSTAGMUS

Nystagmus is a disturbance of ocular posture characterized by a more or less rhythmical oscillation of the eyes This movement may be of the same rate in both directions, or quicker in one direction than in the other. In the latter case the movements are distinguished as the quick and the slow phases. The quick phase is taken to indicate the direction of the nystagmus, so that if the slow phase is to the left and the quick to the right, the patient is said to exhibit nystagmus to the right Nystagmus may occur when the eyes are in the position of rest, or only on deviation in certain directions or on convergence. The movement may be confined to one plane, horizontal or vertical, or occur in more than one plane—rotary nystagmus. Nystagmus may be associated with a rapid rotary tremor of the head, or with jerky vertical movements of the eyelids. The acquired forms may cause an apparent movement of objects seen by the patient.

The nature of nystagmus can be best appreciated by recalling the statement made in a previous section (on p. 69) that the posture of the eyes is influenced reflexly by a number of factors of which the most important are impulses derived from the retinae, the labyrinths, and the cervical spine. Nystagmus is a disturbance of ocular posture which may be due to (1) defective or abnormal retinal impulses, (2) abnormal labyrinthine impulses, (3) lesions of the cervical spinal cord, (4) lesions involving the central paths concerned in ocular posture, and (5) weakness of the ocular muscles (6) It may also be a congenital abnormality of unknown aetiology, and (7) it is rarely hysterical.

(1) Nystagmus of Retinal Origin.

(i) Amblyopia coming on in early life may cause nystagmus if some vision is retained and especially if macular vision is impaired. The visual impairment renders ocular fixation defective, and a pendular nystagmus results.

(ii) *Miners' nystagmus* has been attributed to the relative inefficiency of macular vision in a dim light as a result of the absence of rods in the macula On this hypothesis the defectiveness of macular vision causes defective fixation It is also believed that neurosis plays a part in maintaining, if not in originating, the disturbance.

(iii) *Optic nystagmus*. Optic nystagmus is the term applied to the nystagmus evoked by a succession of moving objects passing before the eyes. A familiar example is the nystagmus which occurs in an individual looking out of the window of a moving train The slow phase is in the direction in which the landscape appears to move and the quick phase is in the direction in which the train moves. This form of nystagmus can be reproduced by making a subject look at a rotating drum which bears a succession of figures arranged at intervals The slow phase occurs in the direction of movement of the drum. It probably depends upon a reflex path originating in *the retina and passing to the visual cortex in the occipital lobe*, whence it is relayed through the white matter of the hemisphere to the oculogyric centre in the second frontal convolution. Neither *hemianopia nor central scotoma abolishes optic nystagmus, but it* may be lost to the opposite side when a lesion involves those areas of the temporal and parietal lobes lying between the visual cortex and the second frontal convolution. (Fox and Holmes, 1926.)

(2) Labyrinthine Nystagmus.

The physiological aspects of labyrinthine nystagmus are considered elsewhere (p. 180). Appropriate stimulation of the horizontal semi-

circular canals evokes horizontal nystagmus, and of the vertical canals, rotary nystagmus. Acute lesions of the internal ear, whether primary or secondary to disease of the middle ear, cause nystagmus, usually rotary, and with the quick phase as a rule towards the opposite side. The amplitude of the oscillation is increased when the eyes are deviated in the direction of the quick phase and *diminished* on fixation in the direction of the slow phase. Chronic labyrinthine lesions often lead to fine rotary nystagmus on lateral fixation to one or both sides, especially to the side of the lesion.

(3) Nystagmus due to Spinal Cord Lesions.

Nystagmus is not uncommonly seen in cases in which a lesion involves the cervical region of the spinal cord, and is then probably due to defect of afferent impulses from the cervical spine.

(4) Nystagmus due to Central Lesions.

Nystagmus is a common symptom of lesions of the brain-stem and cerebellum. With cerebellar lesions nystagmus may occur on fixation in any direction, the slow phase being towards the position of rest and the quick phase towards the periphery. With a unilateral cerebellar lesion it is present in both eyes and is most marked on conjugate deviation *to the side of the lesion*. It may occur as a result of lesions involving the cerebellar connexions within the brain-stem, the vestibular nucleus, and, probably, the posterior longitudinal bundle. Disseminated sclerosis is the commonest cause. Nystagmus of central origin also occurs in cases of Friedreich's ataxia and other hereditary ataxias, encephalitis, syringomyelia, tumours, and vascular lesions of the brain-stem and cerebellum. It is rare in syphilis.

(5) Nystagmus due to Weakness of the Ocular Muscles.

A peripheral cause of nystagmus, in weakness *of the ocular muscles* required to maintain a posture of conjugate deviation, seems the best explanation of its occurrence in such conditions as polyneuritis, especially alcoholic polyneuritis, myasthenia gravis, botulism, and various forms of poisoning.

(6) Congenital and Familial Nystagmus.

Nystagmus may be present from birth, and in several members of the same family, sometimes in successive generations. Congenital nystagmus is usually a fine pendular oscillation present at rest and on fixation in all directions, but more than one variety occurs. There may be an associated oscillation of the head. There is usually no subjective movement of objects. Its cause is unknown, but *it may* be associated with other ocular defects involving poor vision such as

albinism, astigmatism, or amblyopia. It may be inherited as a Mendelian dominant or as a sex-linked recessive, and males are affected three times as often as females.

(7) Hysterical Nystagmus.

Hysterical nystagmus disappears when ocular fixation is unconscious and reappears on testing the eye movements. It may be associated *with spasm of convergence.*

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8. THE PUPILS AND THE EYELIDS

THE INNERVATION OF THE PUPILS

The size of the pupil is under the control of two mutually antagonistic muscles, the circular muscle of the iris, the sphincter pupillae, which causes contraction and is innervated by the third nerve, and the radial fibres of the iris which cause dilatation and receive their nerve-supply from the cervical sympathetic.

The Irido-dilator Fibres.

Little is known about the innervation of the pupil above the midbrain The experimental work of Karplus and Kreidl, however, points to a path for pupillary dilatation from the frontal cortex to the hypothalamus and thence into the cerebral peduncle Such a corticofugal path appears necessary to explain the occurrence of pupillary dilatation in states of emotion. The irido-dilator fibres continue downwards in the tegmentum of the pons, medulla, and the cervical cord to the lateral horn of the grey matter of the eighth cervical and first and second dorsal segments. *From the cells of these lateral horns the preganglionic fibres take origin and leave the cord by the corresponding anterior roots*. From the spinal nerves they pass by the white rami communicantes of the sympathetic to the cervical sympathetic nerve-trunk to end in the superior cervical ganglion The postganglionic fibres start from this ganglion and join the internal carotid plexus with which they enter the skull and from which some pass to the *ophthalmic division of the trigeminal nerve* and reach the pupil by the nasociliary and long ciliary nerves, while others go from the carotid plexus through the ciliary ganglion without interruption and into the short ciliary nerves.

The Irido-constrictor and Ciliary Fibres.

The irido-constrictor fibres probably originate in the nuclei of Edinger Westphal. Entering the third nerve, they terminate in the ciliary ganglion, from which postganglionic fibres arise which pass by the short ciliary nerves to the circular muscle of the iris. The ciliary fibres follow the same route except that they probably arise in the median nucleus of Perlia and terminate in the ciliary muscle, contraction of which allows the lens to become more convex and so accommodates the eye for near vision.

Paralysis of the Sphincter Pupillae.

The constrictor muscle of the iris may be paralysed as a result of a lesion involving the irido-constrictor fibres at any point between the nucleus of Edinger-Westphal and the eye. The pupil is widely

dilated owing to the unantagonized action of the irido-dilator muscle, and the reaction to both light and accommodation-convergence is lost Paralysis of the sphincter pupillae occurring without paralysis of the extra-ocular muscles is usually due to a lesion either of the nucleus of Edinger-Westphal or of the ciliary ganglion.

Paralysis of the Dilator Pupillae: Ocular Sympathetic Paralysis.

Paralysis of pupillary dilatation is due to a lesion of the irido-dilator fibres of the sympathetic. The pupil is constricted—myosis—by the unopposed irido-constrictor muscle, and fails to exhibit *the normal dilatation when the eye is shaded, in states of pain and emotional excitement*, and reflexly when the skin of the same side of the neck is scratched with a pin—the cilio-spinal reflex. The irido-dilator fibres throughout their course are close to the other fibres of the ocular sympathetic, viz, those which produce tonic elevation of the upper lid and tonic protrusion of the eyeball by means of the unstriped muscle of the orbit. Paralysis of the dilator of the iris is therefore *usually associated with paralysis of these muscles also,* manifested in slight ptosis and enophthalmos (Horner's syndrome).

The myosis of the Argyll Robertson pupil has been attributed to a lesion of the irido-dilator fibres in the midbrain. Myosis may also occur with lesions of the pons, as in the pin-point pupils of pontine haemorrhage, and of the lateral part of the medulla, as in thrombosis of the posterior inferior cerebellar artery. In the spinal cord the *lateral horns of the upper dorsal region may be involved in a variety* of lesions. The sympathetic white rami may be destroyed by trauma, as in the Klumpke type of birth palsy of the brachial plexus, and the cervical sympathetic may be damaged in the neck by trauma or pressure, especially from enlarged cervical lymph glands.

Within the cranium the postganglionic fibres may be damaged by the pressure of a tumour or aneurysm behind the orbit.

Paralysis of Accommodation.

Paralysis of accommodation may be produced by lesions involving the median nucleus of Perlia, the third nerve, or the ciliary ganglion. As an isolated ocular phenomenon it is found in diphtheria, in which condition the lesion is according to some authorities nuclear, according to others, neuritic, and according to yet others, in the ciliary *muscle.*

Inequality of the Pupils.

Inequality of the pupils may occur when one is either pathologically small or pathologically large, or when one is of moderate size

but fails to react to light; in which case the normal one will be the
larger when it is dilated and the smaller when it is constricted. These
various abnormalities can be interpreted in the light of the facts set
out above. Irregularity of the pupils is frequently present in syphilis,
and sometimes in encephalitis lethargica and other conditions. In
such cases it is probably due to lesions at or near the nucleus and must
be distinguished from the irregularity produced by local lesions of the
iris, especially iritis

Action of Drugs on the Pupil and Ciliary Muscle.

Certain drugs influence the pupil and accommodation when applied
to the eye

Pilocarpine and physostigmine (eserine) cause constriction of the
pupil and spasm of accommodation by stimulating the nerve-endings
of the third nerve in the pupil and ciliary muscle. Atropine causes
dilatation of the pupil and paralysis of accommodation by paralysing
the same nerve-endings. I have seen several patients with iridoplegia
produced by belladonna accidentally introduced into the eye by the
fingers after using belladonna liniment. Cocaine causes dilatation of
the pupil by stimulating the nerve-endings of the sympathetic fibres.
The action of morphine in causing irido-constriction is central, not
peripheral.

THE PUPILLARY REACTIONS

The Light Reflex.

If one eye is exposed to light, a constriction of both pupils normally
occurs The response of the pupil of the eye upon which the light
falls is called the direct reaction, that of the opposite pupil the
consensual reaction. In eliciting the light reflex the patient should
be asked to look at a distant object in order to eliminate the contrac-
tion of the pupil on accommodation convergence, and the eye not
being tested should be covered in order to eliminate the consensual
reaction. The path of the fibres concerned in the light reflex is not
accurately known throughout its course. The afferent impulses from
the retina follow the path of the visual afferent fibres as far as the
optic tracts, with a similar decussation of those from the nasal halves
of the retina at the optic chiasma. It is unknown whether the
reflex fibres are identical with those concerned in vision, or whether,
as some have supposed, two separate sets of fibres exist for these
functions On leaving the optic tracts the reflex fibres separate
from the visual and according to Magoun, Atlas, Hare, and Ranson
(1936) in the monkey they pass through the brachium of the superior
colliculus, but do not enter it, turning rostrally and medially into the
pretectal region and then descending to the oculo-motor nuclei.

accommodation-convergence implies that the lesion does not involve the fibres concerned in this reaction. Reflex iridoplegia may occur as a result of lesions in the following situations.

1 *Lesions of the Optic Nerve.* Accommodation-convergence and the associated irido-constriction can occur in the absence of vision, for example, if an individual who has become blind tries to look at the end of his nose. Consequently a lesion of the optic nerve severe enough to impair the conduction of the afferent impulses concerned in the light reflex can cause loss of that reflex with retention of the reaction on accommodation-convergence.

2 *Lesions of the Optic Tract.* Destruction of one optic tract causes loss of the light reflex when the temporal half of the ipsilateral retina and the nasal half of the contralateral retina are illuminated, though the reflex remains elicitable from the other half of each retina. Homonymous hemianopia due to a lesion of the optic tract can sometimes thus be distinguished from a similar hemianopia due to a lesion of the optic radiation which does not interrupt the light reflex. (Wernicke's hemianopic reaction)

3 *Central Lesions.* There is abundant evidence that reflex irido-plegia may be produced by *lesions of the upper part of the midbrain.* It has been observed in cases of tumour involving this region, as a result of vascular lesions, in encephalitis lethargica, as a rare manifestation of disseminated sclerosis and syringomyelia, in alcoholic polyneuritis, diabetes mellitus, chronic hypertrophic interstitial *neuritis, and as a result of a traumatic lesion of the upper midbrain.* Syphilis is, of course, far the commonest cause of the Argyll Robertson pupil as above defined, which is usually present in general paralysis and tabes and frequently in meningo-vascular syphilis. The site of the lesion responsible for this sign in syphilis of the nervous system is disputed, but the most plausible hypothesis would place it in the upper half of the midbrain, near the aqueduct of Sylvius, where it may be supposed to interrupt the fibres approaching the irido-constrictor nucleus.

4 *Lesions of the Motor Path.* It is stated that lesions of the third nerve may abolish the reaction of the pupil to light without that on accommodation-convergence. Such a dissociation can unquestionably occur as a result of lesions in or behind the eye, and it has been described in a number of cases of trauma involving the eye.

Myosis is not necessarily associated with loss of the pupillary light reflex. The Argyll Robertson pupil of tabes, however, is much contracted, and its constriction is due to associated involvement of the descending fibres of the ocular sympathetic which also explains the loss of reflex dilatation in response to painful stimuli, and the ptosis, so characteristic in tabes

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Tonic Pupils and Absent Tendon Reflexes.

Definition. A syndrome of unknown aetiology and pathology characterized in its fully developed form by abnormalities in the reactions of one or both pupils to light and accommodation and absence of the tendon reflexes. The features of the tonic pupil were first described by Ware in 1813. They were rediscovered in 1902 by Strasburger and Saenger independently. An example of the complete syndrome was shown by Markus in 1905. Our present knowledge is based upon clinical observations of Foster Moore (1924, 1931), Holmes (1931), and Adie (1931 a, 1931 b, and 1932)

Synonym. Adie's syndrome.

Aetiology.

The disorder occurs almost exclusively in females and the age of onset is usually during the third decade. Beyond this nothing is known as to its aetiology. It is entirely unrelated to syphilis

Symptoms.

The onset is usually sudden, the patient or her friends noticing that one pupil has become larger than the other. Sometimes the first complaint is of mistiness of vision in one eye. The pupillary abnormality is unilateral in about 80 per cent. of cases. The affected *pupil is moderately dilated and is therefore usually larger than its* fellow. When tested by ordinary methods the reaction of the affected pupil to light, both direct and consensual, is either completely or almost completely absent. Sometimes, however, a sluggish reaction to light can be elicited after the patient has remained in a dark room for about half an hour. The characteristic feature, however, is the response of the pupil to convergence. Whereas a hasty examination

may suggest that the pupil does not react at all on convergence, nevertheless if the patient be made to gaze fixedly at a near object the pupil, sometimes after slight delay, contracts very slowly through a range which is often greater than normal, so that the affected pupil actually becomes smaller than the normal one. When convergence is relaxed dilatation of the pupil begins either at once or after a slight delay and proceeds even more slowly than contraction. This is the tonic pupillary reaction.

The tonic pupillary reaction, however, is not always present but may be replaced by sluggishness or even absence of the reaction on convergence. The pupil may thus be fixed to light and on convergence. Accommodation may also be tonic so that after the gaze has been fixed on a near object some seconds may elapse before this becomes clear.

Some abnormality in the tendon reflexes is usually present, the ankle jerks, knee jerks, and arm jerks being diminished or lost in this order of frequency. Occasionally the tonic pupil occurs with normal reflexes or, less frequently, normal pupils with absent tendon reflexes. No other abnormality is found in the nervous system or elsewhere.

Diagnosis.

It is important to distinguish the tonic pupil from the Argyll Robertson pupil, but this is not difficult if it is borne in mind that the Argyll Robertson pupil is smaller than normal, does not react to light, and reacts promptly and fully on convergence, and dilates incompletely to mydriatics, differing in all these respects from the typical tonic pupil.

Prognosis.

The syndrome is permanent but has no ill effect beyond the inconvenience attaching to tonic accommodation. Patients have been observed in whom the condition of the pupil has remained unchanged for thirty or forty years. Occasionally it spontaneously changes its size and, rarely, the other eye becomes affected some time after the first.

Treatment.

No treatment is of any value.

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THE INNERVATION OF THE EYELIDS

Two muscles act as levators of the upper eyelid, the levator
palpebrae superioris, which is innervated by the third nerve, and
Muller's palpebral muscle, part of the smooth muscle of the orbit,
which receives its nerve-supply from the cervical sympathetic.
Closure of the lids is brought about by the orbicularis oculi, the
motor nerve of which is the facial.

Retraction of the Upper Lid.

Retraction of the upper lid is not an uncommon abnormality
attributable to a relative or absolute shortening of the elevating
muscles, perhaps especially of the smooth muscle. When present it is
exaggerated when the patient voluntarily elevates his eyes, and it is
responsible for the lag of the upper lid in following the downward
movement of the eye, which is known as 'von Graefe's sign'. Lid
retraction is most frequently encountered in exophthalmic goitre,
but, as Collier has pointed out, it may be produced by a lesion in the
upper part of the midbrain, especially one involving the posterior
commissure It may follow a vascular lesion in this situation and it
is also met with in tabes, disseminated sclerosis, encephalitis lethargica
(especially the Parkinsonian form), tumour of the midbrain, and as
a congenital abnormality.

Retraction of the upper lid may be unilateral or bilateral and may
occur with or without exophthalmos When it is due to a lesion in
the upper part of the midbrain it may be associated with weakness
of conjugate elevation of the eyes or with reflex iridoplegia.

Ptosis of the Upper Lid.

Ptosis of the upper lid may be the result of paralysis of either
the levator palpebrae superioris or of the orbital smooth muscle
In the latter case the drooping of the lid is comparatively slight.
Complete paralysis of the levator, however, causes closure of the eye
It is necessary to distinguish between ptosis due to a lesion of the
sympathetic and that due to paresis of the levator. This may be done
by observing the reaction of the lid when the patient voluntarily
elevates the eyes. Normally, elevation of the upper lid occurs as an
associated movement with elevation of the eyes. In ptosis of sym-
pathetic origin the amplitude of this associated movement is normal

In ptosis due to paresis of the levator it is diminished. Over-action of the frontalis muscle is commonly present in a patient with ptosis. This muscle normally contracts in association with the levator palpebrae, and when the latter muscle is paralysed the increased effort made by the patient to elevate the lid involves an increased contraction of the frontalis muscle, physiologically comparable to *secondary deviation of a conjugate ocular muscle in paralytic stra-bismus*. Paralysis of the levator may be due to a lesion involving the nucleus of the third nerve or the third nerve-trunk or its superior division within the orbit or to disorder of function at the myoneural junction in myasthenia gravis. It may be congenital. A lesion of the ocular sympathetic responsible for ptosis may occur within the brain-stem, spinal cord, and eighth cervical and first and second dorsal anterior roots and spinal nerves, and the cervical sympathetic trunk. It is usually associated with other signs of ocular sympathetic paralysis, namely, myosis and enophthalmos.

Exophthalmos and Enophthalmos.

The smooth muscle of the orbit is normally in a state of sufficient tonic contraction to produce some protrusion of the eyeball. Paralysis of this muscle causes slight enophthalmos: it is less certain that exophthalmos is ever due to its over-activity. The commoner causes of exophthalmos are (1) exophthalmic goitre; and (2) the closely associated exophthalmic ophthalmoplegia; (3) primary tumours within the orbit, especially of the optic nerve and its sheath; (4) diseases of the nasal air sinuses, empyema, mucocele, and carcinoma; (5) retro-orbital intracranial tumours, especially meningiomas and aneurysms, (6) orbital cellulitis, (7) thrombosis of the cavernous sinus, and (8) carotid-cavernous sinus aneurysm. Less common causes are cranio-stenosis, Christian Schuller's disease, chloroma, and metastatic tumour of the suprarenal (Hutchison type).

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9. SPEECH AND ITS DISORDERS

THE NATURE OF SPEECH

Psychological Considerations.

Speech is an extremely complex activity. In order to understand its nature it is necessary to trace its development in the individual from infancy The first step in the development of speech occurs when the young infant begins to associate sounds with the perception of objects, for example, when its nurse shows it a cat and says 'pussy', the sounds which form 'pussy' become associated with the visual images aroused by the sight of the cat. In the case of common objects other images, tactile, auditory, olfactory, and gustatory, combine with visual images in the perception of the object, and these become associated with those heard sounds which constitute its name. Nouns, i.e names of objects, are the simplest parts of speech and those which are learned first. Other words—adjectives, verbs, prepositions, &c — involve the association of sounds with a greater degree of abstraction from the perceptual situation. As a child learns to speak it endeavours to reproduce the sounds which it hears and thus kinaesthetic sensations derived from the muscles of articulation become associated with the sounds produced by the speaker's voice. Illiterate individuals never pass beyond this stage in the development of speech.

When the child learns to read it does so by associating visual signs, i e letters and words, with the sounds which it has already learned Through reading aloud, written words become linked with heard words and with the kinaesthetic sensations of speech. In writing, movements of the hand are employed to reproduce visual signs similar to those which form the basis of reading Since in writing one reads as one writes there exists a close link between the perception of the visual signs which constitute letters and words and the kinaesthetic sensations derived from the fingers

Words therefore are symbols. A spoken word is to the hearer an auditory symbol of an object, action, or relationship; a written word in the first instance acquires its symbolic significance through its association with heard speech, that is, symbolic sounds. Words as symbols possess meanings, but these meanings are of an elementary nature. In fully developed speech individual words possess significance only in relationship with other words. The unit of meaning is then a sentence or even a series of sentences. Speech, therefore, is the communication of meanings by means of symbols, which usually take the form of spoken or written words. Meaning may, however, be communicated by gesture, and gesture meanings have been especially elaborated in the manual speech of the deaf and

dumb. In reading Braille printing the blind utilize tactile instead of visual sensations Mathematics and music also involve the use of written symbols.

Hughlings Jackson first pointed out that speech is not always used for the communication of meanings—propositional speech, as he called it—but may also constitute the expression of feeling, in which case it may have no propositional value.

How far is thought dependent upon speech ? It has been maintained that we think in words and that normal speech functions are therefore necessary for thought. The process of logical thought is probably subject to large individual variations depending upon whether the thinker chiefly utilizes visual or auditory images. It appears to be true, however, that internal verbal formulation is not necessary, at least for the simpler forms of logical thought. It is probably required for more abstract thinking and is necessary for the communication of the products of thought to others.

Physiological and Anatomical Considerations.

At the psychological level the meaning of a written or a spoken word is the outcome of the association of the given visual and auditory sensations with other forms of sensation in the past. A meaning is thus based upon a constellation of associations built up by experience. At the physiological and anatomical levels the basis of such meanings is presumably a linkage of neurones. Visual impulses reach the cerebral cortex in the region of the calcarine fissure of the occipital lobes ; auditory impulses in the posterior part of the superior temporal convolution. Kinaesthetic impulses from the muscles of articulation and from the upper limb terminate in the lower half of the post-central convolution. It is to be expected therefore that the anatomical linkages of neurones upon which verbal meanings depend will join together these regions of the cerebral cortex, and these are found in the tracts of white matter known as association fibres which underlie the grey matter of the cerebral cortex.

For reasons which are little understood about 90 per cent. of persons are right-handed, and in these the left cerebral hemisphere plays the predominant role in speech. The right hemisphere does so in the remainder The important associational parts just described are therefore situated in the left hemisphere in right-handed persons, but sensory impulses concerned in the reception of speech also reach the auditory and visual regions of the right cerebral cortex, which are linked to the left hemisphere by paths passing through the corpus callosum Whether the right hemisphere plays any further part in speech is problematical, though it has been credited with some power to compensate for deficiencies in the functions of the left, and

has also been held responsible for some symptoms in patients suffering from aphasia.

The posterior half of the left cerebral hemisphere is thus the site of *those neuronic linkages which underlie the elaboration of meanings* in response to auditory and visual stimuli, i.e. the comprehension of heard and written speech. Since articulated speech is the expression of meanings it must be the outcome of the activity of a part of *the brain which at least overlaps that concerned in the reception of speech*, for the anatomical basis of meanings is common to both. Articulation involves movements of the jaw, lips, tongue, palate, larynx, and of the respiratory muscles, which are represented in the lowest part of the precentral convolution. If meanings are to gain articulate expression the posterior half of the left hemisphere must be linked to the lowest part of the precentral convolution. An important part in this association is played by the external capsule, which is a band of white matter running from the tip of the temporal lobe beneath the cortex of the island of Reil to the lower part of the precentral convolution and the posterior part of the second and third frontal convolutions. Speech requires co-ordinate bilateral movements of the muscles of articulation, and this co-ordination is effected by fibres passing from the lower part of the left frontal lobe to the corresponding region of the right hemisphere by the corpus callosum. From the *lower part of the precentral convolutions the motor fibres* concerned in articulation pass downwards in the pyramidal tracts and after decussation end in the trigeminal and facial nuclei, the nuclei ambigui and the hypoglossal nuclei in the pons and medulla, whence the lower motor neurones run in the corresponding cranial nerves to the lips, soft palate, tongue, and larynx. Cortico-spinal fibres similarly innervate the diaphragm and intercostal muscles. As in the case of other motor activities, the cerebellum *exercises a co-ordinating and regulating influence upon articulation.*

DYSARTHRIA

We are now in a position to draw a distinction between speech and articulation. Speech is the term employed for the whole process by which meanings are comprehended and expressed in words. Articulation is the motor function whereby words, having been formulated are converted into sounds. Dysarthria is a disorder of articulation It therefore does not involve any disturbance in the proper construction and use of words. In the dysarthric patient symbolic verbal formulation is normal. Only the mechanism of verbal sound production is faulty. When this is so severely affected that the patient is totally unable to articulate, he is said to be *anarthric*.

The following are the principal causes of dysarthria:

(1) Upper Motor Neurone Lesions.

The articulatory muscles on each side appear to be innervated by both cerebral hemispheres. Hence a unilateral pyramidal lesion, for example in the internal capsule, does not cause permanent dysarthria. Dysarthria is produced, however, by bilateral pyramidal lesions, due, for example, to congenital diplegia, vascular lesions of both internal capsules, degeneration of both pyramidal tracts, as in amyotrophic lateral sclerosis, and lesions such as tumours involving both pyramidal tracts together in the midbrain. Following such lesions the articulatory muscles are weak and spastic and the tongue appears smaller and firmer than normal The jaw-jerk and the palatal and pharyngeal reflexes are exaggerated. Speech is slurred, production of consonants, especially labials and dentals, being severely affected. Spastic dysarthria is usually associated with dysphagia and often with impairment of voluntary control over emotional expression, a syndrome which has eceived the unsatisfactory name of 'pseudo-bulbar palsy'.

(2) Parkinsonism.

In Parkinsonism articulation is impaired, partly as a result of muscular rigidity Thus in hepato-lenticular degeneration and in Parkinsonism articulation is slow and slurred owing to immobility of the lips and tongue and the pitch of the voice is monotonous. In severe cases speech may be unintelligible.

(3) Disorders of Co-ordination.

The co ordination of articulation suffers severely when the vermis of the cerebellum is damaged and also when lesions involve the cere-bellar connexions in the brain-stem. Speech in such cases is often explosive and associated with violent grimaces. Syllables may be slurred or unduly separated—scanning or syllabic speech. Ataxic dysarthria of this character is seen after acute lesions of the cere-bellar vermis and in disseminated sclerosis and the hereditary ataxias. Ataxic speech also occurs in chorea and athetosis and in these dis-orders irregular respiration contributes to the dysarthria.

(4) Lower Motor Neurone Lesions.

Lower motor neurone lesions cause wasting and weakness of the muscles of articulation. In the early stages the pronunciation of labials suffers most Later progressive weakness of the tongue im-pairs the production of dentals and gutturals, and weakness of the soft palate gives the voice a nasal quality. To this may be added impairment of phonation and finally speech becomes completely

impossible. Progressive bulbar palsy is the commonest example of this It may also occur in syringobulbia and polyneuritis cranialis.

Combinations of these varieties of dysarthria are common, for example, in disseminated sclerosis the articulatory muscles may be both spastic and ataxic and in amyotrophic lateral sclerosis a combination of upper and lower motor neurone lesions may be present.

(5) Myopathies.

Disease of the muscles, such as occurs in myasthenia gravis and facial muscular dystrophy, leads to dysarthria similar to that resulting from lesions of the lower motor neurones. In myasthenia fatiguability may cause increasing slurring of speech if the patient is asked to count. In the myotonias tonic muscular contraction may add a spastic character to the speech.

Treatment.

Little can be done when dysarthria is due to a progressive disorder, but in children suffering from congenital diplegia, athetosis, and chorea much can be accomplished. Speech training must consist of (1) vocal gymnastics, (2) breathing exercises, and (3) the practice of muscular relaxation, and should be combined with general remedial physical exercises.

PALILALIA

Palilalia is a rare disorder of speech, the nature of which is obscure As its name implies (palin, again, lalein, to chatter), it is characterized by repetition of a phrase which the patient reiterates with increasing rapidity. Palilalia most frequently occurs as a symptom of the Parkinsonian syndrome following encephalitis lethargica and in pseudo-bulbar palsy due to vascular lesions. In one of my patients it occurred as a temporary phenomenon as a result of compression of the medulla. It is difficult to understand why a lesion involving the lower motor mechanisms of speech should cause a disorder of the formation of phrases.

MUTISM

Mutism is the term applied to a complete loss of speech in a conscious patient in the absence of organic disease of the nervous system. It occurs in the psychoses, for example in cyclothymia, as a result of extreme depression or mental retardation, and in schizophrenia. It is also met with in hysteria. In the psychoses the severity of the mental disorder is always apparent and the mute patient is usually unable to write. In hysterical mutism other hysterical symptoms such as convulsions, rigidity, and anaesthesia are usually present.

The treatment of hysterical mutism involves the general treatment of the hysterical state, see p. 916. The treatment of the symptom consists of re-education in speech, the patient being shown how to place his lips and tongue, then induced to phonate and so convinced that he is able to speak.

APHONIA

In aphonia phonation is lost but articulation is preserved; hence the patient talks in a whisper. Aphonia may be the result of organic disease causing bilateral paralysis of the adductors of the vocal cords (see p. 199) or of disease of the larynx, for example, laryngitis. It is most commonly a symptom of hysteria, in which case the patient, though unable to phonate when speaking, can do so when coughing.

The treatment of hysterical aphonia involves the general treatment of the hysterical state, see p. 916, and re-education in phonation. By making the patient modulate his cough he can be brought to phonate vowels at different pitches and can then be induced to combine these with the consonants which he is able to whisper. A time-honoured method of treating hysterical aphonia is the application of faradism to the pharynx. This elicits from the patient a cry, which is used to convince him that he can still speak.

STUTTERING

Definition.

A disturbance of articulation not caused by organic nervous disease but closely linked with left-handedness and characterized by abrupt interruptions of the flow of speech or the repetition of sounds or syllables.

Aetiology.

The close association of stuttering with left-handedness indicates that in many cases it possesses an anatomico-physiological basis. Orton states that stuttering children fall into four groups: (1) those in whom an enforced shift from the left to the right hand has been carried out by parents or nurse; (2) those who have been slow in selecting a master-hand and show considerable intergrading; (3) those who fulfil neither of these conditions and have a strong family history of stuttering; and (4) those with no shift of handedness and no family history of stuttering. In this group, however, other types of speech defect or left-handedness can usually be found in the family. Moreover, stuttering usually begins either at the age of two or three when the child is beginning to talk and to develop a master hand or between the ages of six and eight in a child that has hitherto spoken fluently, i.e. at the age at which reading and writing are being

acquired. It is thus clear that the localization of the speech 'centres' in the right cerebral hemisphere tends to cause stuttering, especially if the dominance of the right hemisphere is impaired by an attempt to make the right the master hand.

The role of neurosis is difficult to assess since stuttering in itself is likely to evoke shyness and neurotic reactions. Orton maintains that child stutterers who are investigated before the overlay of neurosis has developed show no more psychological abnormalities than other children. Boys suffer four times as often as girls.

Symptoms.

The flow of speech may be broken by pauses, during which it is entirely arrested, or by the repetition of sounds or syllables. The pause may be filled with grunts or hisses and stuttering is frequently associated with facial contractions or tics involving the limbs or even the whole body. Dentals (t, d), labials (p, b), and gutturals (k and hard g) are the consonants which are usually the most troublesome to the stutterer, especially when they occur at the beginning of a word. Stutterers often go out of their way to avoid certain words by reconstructing sentences and may employ tricks to enable them to achieve correct pronunciation, for example spelling a word before pronouncing it. They can usually sing and may be able to recite without hesitancy.

Prognosis.

Mild stuttering tends to disappear spontaneously. In severe cases considerable improvement and often complete cure can be achieved by thorough treatment.

Treatment.

When stuttering occurs in a left-handed child who has been made to use the right hand, a return to left-handedness often produces great improvement. Re-education of speech by a trained teacher is essential. Abnormalities in the upper respiratory passages, if present, should first receive appropriate treatment. The role of muscular spasm in the production of stuttering must be explained to the patient, who should be taught to practise relaxation of the muscles concerned in speech. Relaxation should be followed by breathing exercises and by vocal gymnastics, exercises being prescribed in which the lips, tongue, jaw, and palate are moved without the production of sounds. Later the patient begins to practise words, and articulation may at first be facilitated by various devices such as singing, or speaking through a megaphone or in time with a metronome.

In children psychological difficulties at home and at school should

be inquired for, and in adults psychological treatment may be required to straighten a warped personality. At all ages suggestion born of the faith and enthusiasm of the teacher is an essential element in treatment

APHASIA

Aphasia is the term applied to disorders of the comprehension and expression of meanings by means of the symbols employed in speech. Since aphasia strictly interpreted means absence of speech, dysphasia is sometimes employed. The present state of our knowledge—or ignorance—of disturbances of the function of speech has been well characterized by Head as 'chaos'. The terminology employed in the description of aphasia is still to a large extent in bondage to old-fashioned views concerning the psychological nature of speech and outworn conceptions of cerebral localization. Confusion is increased by the fact that different investigators have been animated by different motives. Some, especially the earlier workers, taking localized cerebral lesions as their starting-point, have sought to discover corresponding forms of aphasia, while others have begun at the other end by analysing aphasia as a disturbance of function. The difficulties of the problem are enhanced by the facts that speech is an extremely complex function, that there are marked individual variations in intelligence and in the use of images, and that the lesions responsible for aphasia are frequently large and massive.

It would appear least confusing and most in accord with modern neurological conceptions to consider aphasia first as a disturbance of function and then to inquire how far disturbance of function can be correlated with cerebral localization.

As we have seen, 90 per cent. of persons are right-handed and in these aphasia is produced only by a lesion involving the left cerebral hemisphere In the remaining 10 per cent. the reverse is true. Exceptions to this rule occasionally occur. For example, aphasia may be produced by a lesion of the right hemisphere in an apparently right-handed individual, but in such cases it has sometimes been found that the patient belongs to a left-handed stock and may therefore be assumed to possess a right-sided localization of his speech *function We have already demonstrated how the comprehension of* speech depends upon the interpretation of auditory and visual images which reach consciousness through the agency of sensory impulses, arriving at the auditory cortex in the temporal lobe and the visual cortex in the occipital lobe The expression of speech by means of sounds requires the activity of motor neurones situated in the lower part of the precentral convolution. It follows that lesions situated

posteriorly to the fissure of Rolando are likely to disturb the comprehension of speech more than its expression, while the reverse is true of lesions situated in front of the fissure of Rolando. It is thus useful to distinguish between 'sensory' or 'receptive' aphasia and 'motor' or 'expressive' aphasia, but this distinction is not absolute. One of Head's most valuable contributions to the study of aphasia has been his demonstration that when speech is disturbed the same type of disturbance underlies both comprehension and expression. The following classification of forms of aphasia is based upon Head's work.

Verbal Aphasia (Motor Aphasia).

In verbal aphasia the expressive aspect of speech suffers severely. In severe cases the patient may be completely speechless or able to say only 'yes' and 'no', and even these words may be inappropriately used and cannot be repeated to order. Emotional speech suffers less than 'propositional', and an otherwise almost speechless individual may be able to swear or utter other emotional ejaculations. With improvement the power of expression gradually returns, but speech is slow, interrupted by pauses, and words are badly pronounced. Polysyllables tend to be slurred. The significance of words as names is unimpaired, however, and grammar is unaffected. In reading aloud speech suffers in the same way as in spontaneous utterance. In writing also the patient exhibits errors in verbal formulation. Written words tend to be incomplete and spelling is defective. Superficially the comprehension of both heard and written speech may appear to be normal. Nevertheless, there is often difficulty in grasping complex meanings, probably because the patient's power of internal verbal formulation is faulty.

There is general agreement that verbal aphasia is usually produced by lesions situated in the posterior part of the third frontal convolution (Broca's area) and the lower part of the precentral convolution.

Nominal Aphasia (Amnestic Aphasia).

In nominal aphasia the patient suffers from an inability to appreciate the symbolic significance of names. This is most evident when he is asked to name an object which is held before him. In severe cases he is quite unable to do so; in milder cases he succeeds with familiar, but fails with less familiar, objects. Characteristically he rejects a wrong name suggested by the examiner. He usually insists that he knows what the object is, but cannot name it, and frequently attempts to convey his recognition by some periphrasis. For example, a patient suffering from nominal aphasia when shown a pair of

spectacles pointed to his ears and said, 'That's what you put on. Shows more strongly for yourself. If you cannot see enough, so you put it on.'

The structure of words is not impaired. Writing exhibits the same nominal defect as articulated speech. There is much difficulty in comprehending spoken and written language owing to failure to recognize the meaning of words.

Nominal aphasia in its mildest forms is a common disturbance of function and may occur as a result of nervousness, fatigue, intoxication, or senility. It is usually present in a severe degree after lesions involving the angular gyrus, but it may also be produced by lesions of the temporal and frontal lobes. The milder degrees of nominal aphasia, therefore, possess little value in the localization of a cerebral lesion.

Syntactical Aphasia (Jargon Aphasia, Agrammatism).

Syntactical aphasia is the term applied by Head to a disturbance of speech in which grammatical coherence is particularly disturbed, agrammatism or paragrammatism. Single words may be comprehensible, but their grammatical relationships are defective. The patient is often voluble and in severe cases pours forth a stream of jargon. Paraphasia, that is, the utterance of non-existent or incorrect words, is common. The comprehension of spoken speech is impaired. Reading is little affected and the patient can usually understand what he reads silently, though if he reads aloud he may be confused by the inaccuracies in his verbal expression of what he sees. Writing is usually less affected than articulate speech. Syntactical aphasia is commonly associated with lesions involving the posterior part of the temporal lobe.

Semantic Aphasia.

Semantic aphasia is the term applied by Head to a disorder of speech characterized by a disturbance of appreciation of meaning at its highest levels. There is little defect of articulated speech. The patient grasps the details of spoken language but fails to understand the general significance of what he hears. A similar defect occurs in reading. The affected individual may be able to read accurately a passage from a newspaper and yet may be quite unable to give an account of it afterwards. In semantic aphasia speech defect appears to merge into a defect of general intelligence. Head considers that this type of aphasia is most frequently associated with a lesion of the supramarginal gyrus.

It will have been seen that in the case of so-called motor aphasia there is little difference between Head's views and those of earlier

workers. In dealing with receptive, aphasia, however, Head emphasizes the fact that a single disturbance of function underlies the disorganization of both the receptive and the expressive elements of speech. Valuable as this approach to the subject is, for *practical purposes clinicians will no doubt continue to employ a classification of speech disorders in which the most prominent disturbance of function is found to be of localizing significance.* On this practical but less scientific basis there is still room for the conceptions of word-blindness and word-deafness.

Word-blindness. Word-blindness, or alexia, is the term applied to a form of receptive or sensory aphasia in which the predominant disturbance of function is an impairment of the appreciation of the meaning of written speech. This disorder may be more or less profound. In its most severe form the patient is unable to recognize the nature of written speech as speech. Written words possess no meaning for him. Such patients have been described as 'word-sight-blind'. When the disturbance of function is less severe, words are recognized as words and the patient may be able to read aloud, but he fails to appreciate the meaning of what he reads—'word-meaning-blindness'. Impairment of the appreciation of written speech seriously interferes with writing. Word-blindness is commonly a symptom of a lesion of the left parieto-occipital region, especially of the angular gyrus.

Word-deafness. Word-deafness is a form of receptive or sensory aphasia in which the comprehension of spoken speech is seriously impaired. As in the case of word-blindness, the disturbance of function may be more or less severe. In the most severe form the patient, although not deaf, may not distinguish the sounds of words from other sounds. He may still be able to read, write, and speak with fair accuracy, though he cannot repeat words which he hears or write from dictation. When the disturbance of function is less severe the patient distinguishes words from other sounds and may be able to repeat them, but fails altogether to recognize that they possess meaning. These two forms of word-deafness are distinguished as 'word-sound-deafness' and 'word-meaning-deafness'. The latter is the form of aphasia most frequently associated with *echolalia*, the term applied to the repetition by the patient of words spoken to him. Such a patient, if asked, 'How are you to-day?' replies, 'How are you to-day?' Word-deafness is usually the result of lesions of the middle and posterior portions of the third temporal convolution on the left side.

Agraphia. Agraphia is the term applied to a loss of the ability to express meanings in written language. To establish the presence of agraphia, *which is not infrequently associated with paralysis of the right arm,* it must be shown that the patient cannot write with

the left hand. Writing is a complex function closely related to the comprehension of written speech, and a patient who suffers from word-blindness is usually also unable to write correctly. In the absence of word-blindness agraphia is most frequently the result of a lesion in the posterior part of the second frontal convolution, which interferes with nervous impulses reaching the area of the precentral convolution concerned in movements of the hand. Such a lesion no doubt was responsible for the association of agraphia with aphasia in the case of Dr. Samuel Johnson, who, writing to Mrs. Thrale two days after his 'stroke', said: 'In penning this note, I had some difficulty; my hand, I knew not for why, made wrong letters.'

Acalculia Acalculia is the term applied to a defect in the use of mathematical symbols which is usually present in aphasia of the expressive type.

Amusia Amusia, the term applied to a defect of musical expression or appreciation when due to a cerebral lesion, like aphasia may be either expressive or receptive. It is rarer than aphasia and may sometimes follow a right-sided lesion in a right-handed person.

Examination of a Patient with Aphasia.

Examination of a patient with aphasia requires care and patience and should be carried out in a systematic manner. The following scheme of investigation advocated by Collier fulfils all ordinary clinical requirements.

(1) Is the patient right- or left-handed, and, if the latter, did he write with the right hand? (2) What was the state of education as regards reading, writing, and foreign tongues? (3) Does he understand the nature and uses of objects, and can he understand pantomime and gesture, or express his wants thereby? (4) Is he deaf? If so, to what extent and on one or both sides? (5) Can he recognize ordinary sounds and noises? (6) Can he comprehend language spoken? *If so, does he at once attempt to answer a question?* (7) Is spontaneous speech good? If not, to what extent and in what manner is it impaired? Does he make use of wrong words, recurring utterances, or jargon? (8) Can he repeat words uttered in his hearing? (9) Is the sight good or bad; is there hemianopia, or papilloedema? (10) Does he recognize written or printed speech and obey a *written command*? If not, does he recognize single words, letters, or numerals? (11) Can he write spontaneously? What mistakes occur in writing? Is there paragraphia? Can he read his own writing some time after he has written it? (12) Can he copy written words, or from print into printing? Can he write numerals or perform simple mathematical calculations? (13) Can he read aloud? (14) Can he name at sight words, letters, numerals, and common objects? (15) Can he write from dicta-

tion ? (16) Can he match an object with its name, spoken or written, when a series of objects and names are simultaneously presented ? (17) Any other tests, emotional, rhythmical, or musical, which may raise the physiological level of the speech centres. (18) Any other means of proving in what way he can receive and express ideas.

The Causes of Aphasia.

Apart from congenital disturbances of speech described below, aphasia is rare in childhood and increases in frequency with increasing age. It is most frequently met with after middle life, since the commonest cause is a vascular lesion, especially thrombosis. Cerebral haemorrhage causes aphasia less often than thrombosis, because haemorrhage occurs deep in the white matter of the hemisphere more often than in the cortex or subcortical regions Transitory attacks of aphasia may occur as a result of temporary disturbances of cerebral circulation in patients suffering from hyperpiesia or cerebral atheroma, and transitory aphasia occurring in migraine can probably be similarly explained. Cerebral embolism may cause aphasia, but is uncommon compared with other cerebral vascular lesions The varieties of aphasia due to obstruction of the different cerebral arteries are described elsewhere (see pp. 284–5).

Intracranial tumour is the commonest cause of aphasia during the first half of adult life, when cerebral vascular lesions are rare Abscess of the left temporo-sphenoidal lobe may also cause aphasia and so may traumatic lesions involving the 'speech areas'. Apart from abscess, infective lesions of the brain rarely cause aphasia, though it occurs occasionally in encephalitis lethargica and exceptionally in disseminated sclerosis. Acute cerebral lesions causing hemiplegia and attributed to encephalitis are almost the only causes of aphasia in childhood. Neurosyphilis may cause aphasia, either by leading to cerebral thrombosis or to general paralysis In the latter, transitory aphasia may occur as a symptom of a congestive attack and a profound disintegration of speech may develop as a result of the widespread deterioration of cortical function in the later stages, comparable to that which occurs in degenerative cortical disorders, such as Alzheimer's disease and Pick's disease.

Prognosis.

The prognosis of aphasia depends largely upon its cause. When it develops acutely as a result of a vascular lesion, neural shock is responsible for part of the immediate disturbance of function. Consequently a considerable improvement may be anticipated as this passes off. The prognosis appears to be better when aphasia is due to haemorrhage than when an important artery has been obstructed

by thrombosis or embolism, and the outlook is better also when the aphasia is of the expressive, than when it is of the receptive, type. The prognosis is good when aphasia is due to an extracerebral tumour, such as a meningioma, which has compressed but not invaded the brain. In the case of an intracerebral tumour, even if the tumour can be removed, the operation is likely to be followed by an exacerbation of the speech disturbance and little ultimate improvement can be expected. Recovery usually occurs from aphasia due to acute infections of the brain, though acute encephalitis in early childhood may cause permanent speech disturbance, if it leads also to mental deficiency.

Treatment.

The treatment of aphasia requires unlimited patience and is likely to be more successful when the disturbance of speech affects the expressive, than when it involves the receptive, function. In the latter type of aphasia not only has the patient difficulty in understanding what is required of him, but he also fails to understand his own attempts at speech. The aphasic patient requires to be taught on lines similar to those used in teaching a backward child. The various vowel and consonant sounds must be taught separately, the patient being directed to watch the movements of his teacher's lips and tongue. He is then taught to pronounce the names of common objects when he sees them. The names have then to be associated with pictures and finally with simple written words. The scheme of instruction must be adapted to meet the requirements of each individual case and to utilize to the best effect those elements of speech which are least seriously impaired.

CONGENITAL SPEECH DISORDERS

Congenital speech disorders, though uncommon, are of considerable importance, since, unless a correct diagnosis is made, the sufferer may be wrongly regarded as mentally defective and valuable opportunities of treatment may be missed.

Developmental motor aphasia (Orton) is rare. Congenital aphasia is usually of the receptive type. Two varieties of this, congenital word-deafness and congenital alexia, are distinguished, but combined forms occur.

Congenital Word-deafness.

Congenital word-deafness, or congenital auditory imperception, as it has recently been called, is a rare inborn defect of speech. It is frequently familial and may appear in different members of successive generations of a family. Males are affected more frequently than

females in the proportion of 5 to 1. The essential disturbance of function appears to be an inability to appreciate the significance of sounds, although hearing is normal. It may be supposed that there is a lack of the anatomical mechanism whereby sounds become associated with other sensory impressions and with kinaesthetic sensations produced by speech and so acquire meanings. Since the disorder is more profound than merely a lack of appreciation of the significance of words, the term congenital auditory imperception has been proposed for it by Worster-Drought and Allen. There is no evidence as to the pathological nature of the disorder, but it appears likely to be due to an aplasia of the posterior temporal cerebral cortex on both sides.

The defect is present from birth but is not as a rule noticed until the age at which a normal child begins to understand speech and to learn to speak. It is then found that the patient takes no notice when spoken to and does not learn to repeat words. Hearing, however, is normal and the child responds to noises. Spoken language is not understood provided the patient has not learned to lip-read. The appreciation of musical sounds may or may not be defective. Worster-Drought and Allen have pointed out that associated with the word-deafness there may be a defect in appreciating the meaning of written and printed symbols. This is not surprising in view of the large part which hearing plays in learning to read in normal individuals. Speech suffers seriously as a result of auditory imperception. For a number of years the child may not speak at all. Sooner or later, however, most patients acquire a vocabulary of their own, which is comprehensible only to those who have been closely associated with them. The words spoken bear little resemblance to normal words, though they possess meaning for the speaker. This defective form of speech has been called 'idioglossia' and 'lalling'. A well-known example of idioglossia is the pronunciation of the Lord's Prayer by one of Colman's patients, which was as follows: 'Oue tabde ne nah e nedde, anne de di na; i tede ta, i du de di on eeth a te e edde. Te ut te da oue dadé de, e didde ap tetedde, a ne adin to tetedde adase us, ne notte totate, mime, utte enn, to i aitevene, pore e dande, to edde a edde. Ame.'

Although sufferers from congenital word-deafness are frequently found in institutions for the mentally defective, they do not necessarily suffer from any defect in mental capacity but are severely handicapped by the inadequacy of the primary channel through which we learn the meaning of things around us. It is not surprising therefore that the victims of this disorder tend to develop abnormal psychological reactions to their surroundings, especially when they are treated as lazy or mentally defective.

The education of the congenitally word-deaf requires much care and an intelligent appreciation of the nature of their disorder. As in the case of the deaf, they must be educated principally through the sense of sight and should be taught lip-reading, while their sense of touch may also be used to educate them in correct articulation. It is important that attempts should also be made to educate the sense of hearing. If necessary, idioglossia must be suppressed by isolation and enforced silence. The nature of the disability must be taken into account in planning an occupation.

Congenital Alexia.

Congenital alexia seems the best term to apply to a mixed group of individuals who possess in common a defect in learning to read. This condition has been called congenital word-blindness, but a defect which can rightly be so described is the cause in only a small proportion of cases

Congenital alexia is much commoner than congenital word-deafness, and Thomas has estimated that it is present in 1 in every 2,000 London schoolchildren. Like congenital word-deafness it is not uncommonly familial and may occur in more than one generation of the same family. In some cases it may be due to a congenital lack of the ability to appreciate the significance of visual symbols. In many patients, however, visual symbolization appears to be normal, and the defect appears to consist in a break in the process whereby a written symbol is linked with a sound. Consequently the printed word is wrongly pronounced and conversely a dictated word is wrongly spelled

Mirror-writing.

Mirror-writing is the term applied to script which runs from right to left, the letters being reversed and forming mirror images of normal script. Normal individuals can frequently carry out mirror-writing with the left hand, either when writing with the left hand alone or with both hands simultaneously. Since this capacity is present without previous training we must assume that the education of the right hand in normal writing involves the unconscious education of the left hand to perform the same movements in the opposite direction. Such mirror-writing with the left hand may become evident in right-handed individuals who have developed right hemiplegia, and I have known it follow an injury of the occipital region of the brain.

The situation is more complicated than this, however, in patients suffering from congenital alexia who exhibit mirror-writing, for in such individuals mirror-writing appears to be secondary to mirror-reading, as shown by Orton. These children tend to read words from

right to left and pronounce them accordingly. For example 'not' is pronounced 'ton', and if asked to copy words they frequently do so in the reversed order, with or without reversal of single letters. The frequent association of left-handedness with mirror-reading and writing suggests that these disorders may be secondary to a lesion of the left hemisphere which is normally dominant and to a substituted dominance of the right hemisphere.

Congenital alexia usually becomes apparent owing to the child's backwardness in learning to read. This may be wrongly attributed *to a general defect of intelligence or to laziness. Yet by intelligence tests these children are frequently normal and their power of visual imagery is unimpaired. Such children are apt to develop psycho-neurotic reactions to their environment owing to lack of understanding of their disability.*

Treatment must be based upon an understanding of the nature of the child's disability. Attention must be paid to educating the child in the association of syllables with the articulatory movements employed in their pronunciation. The phonetic method of teaching spelling, in which the child learns letters by their sounds and not by their names, should be employed. Special care must be taken in teaching the child to read from left to right. The teacher should point to the letters in this order and the child should be encouraged to do the same with the forefinger of the right hand.

Stress should be laid upon reading for amusement, and in dictation the child should not depend solely upon ear, but should sit by a normal child and be allowed to see what he has written. Educational authorities throughout the child's career should be informed of his disability in order that allowances may be made, especially in examinations

(*For references see pp 105-6.*)

10. APRAXIA AND AGNOSIA

APRAXIA

Apraxia may be defined as an inability to carry out a purposive movement, the nature of which the patient understands, in the absence of severe motor paralysis, sensory loss, and ataxia. For example, a patient who is asked to protrude his tongue is unable to do so on request, though he may carry out inappropriate movements such as opening his mouth. A moment later he spontaneously protrudes his tongue to lick his lips. Normal purposive movements depend upon the integrity not only of the cortico-bulbar and cortico-spinal tracts, but also of association tracts whereby these efferent paths are excited. The idea of the movement, whether formulated

spontaneously or in response to an external command, thus passes into action. Apraxia is the result of interruption of the transcortical fibres thus acting as ideo-motor links. In right-handed individuals purposive motor activity appears thus to be controlled by the posterior part of the left hemisphere, especially perhaps by the supramarginal gyrus Thence fibres pass forwards in the left hemisphere to the precentral convolution and cross to the same convolution on the right side, through the corpus callosum. Lesions in the left parietal lobe are therefore likely to produce bilateral apraxia. Lesions between this region and the left precentral convolution may lead to apraxia of the limbs on the right side, and lesions involving the anterior part of the corpus callosum or of the subcortical white matter on the right side may cause left-sided apraxia. The commonest form of apraxia is that involving the lips and tongue, which is frequently encountered in association with right hemiplegia due to a lesion of the left hemisphere.

Apraxia has been analysed by Liepmann into limb-kinetic apraxia, due to loss of kinetic memories of part of the body, ideo-kinetic apraxia, due to a dissociation between ideational and kinaesthetic processes, and ideational apraxia, in which the general conception of the movement is imperfect, its component parts being correctly carried out but wrongly combined.

Apraxia is usually associated with an impairment of the power to imitate movements. The disturbance of function which underlies apraxia is essentially the same as that responsible for motor aphasia, which may justly be regarded as an apraxia of the purposive movements concerned in speech.

Apraxia is most frequently seen as a result of localized lesions of the brain, especially vascular lesions and tumours. It may also be a symptom of diffuse cerebral inflammatory or degenerative states, such as general paralysis and the presenile cerebral degenerations.

AGNOSIA

The arrival of nerve-impulses at the cortical areas concerned in vision, hearing, and cutaneous and postural sensibility excites crude sensations which have not yet attained the perceptual level involved in the recognition of objects. This is brought about by the association of the sensations excited through one sense channel with memories of sensations derived from other sense channels during *previous experiences of the object. The perception of an object seen* or felt is thus a constellation of sensory images and memories, and the recognition of an object as having been seen before and of its use depends upon the capacity of the primary visual or tactile sensations which it evokes to excite the appropriate constellation of

memories. When by reason of disease of the brain this secondary process fails to occur, the patient fails to recognize the object. This *defect is known as agnosia.*

Visual agnosia is present when the patient, in whom the paths from the retina to the occipital cortex are intact and the latter is undamaged, nevertheless fails to recognize common objects which he clearly sees. This condition may result from lesions in the left parieto-occipital region in right-handed persons. Visual disorientation in space is also a form of visual agnosia. Auditory agnosia implies the failure to recognize sounds in a patient who is nevertheless not deaf. An individual suffering from this disability in a severe form will fail to appreciate not only the nature of words but also musical tunes. This results from a lesion of the left temporosphenoidal lobe in right-handed persons. Sensory agnosia is one form of the disorders comprised under the more general term astereognosis. The patient, though not suffering from gross sensory defect in the fingers or hand, is nevertheless unable to recognize an object placed in the hand. This may be produced by a lesion of the parietal lobe situated posteriorly to the post-central convolution at the level of the hand area. Agnosia usually only affects the recognition of objects through one sensory channel. Thus a patient suffering from visual agnosia, who cannot recognize a key when he sees it, can usually recognize it when it is placed in his hand. Conversely, a patient who cannot recognize objects placed in his hand recognizes them readily when he sees them.

An unusual but interesting form of agnosia is a defect of awareness of a part of the body. Finger agnosia (Gerstmann, 1924, 1931–2) is characterized by an inability to recognize and select individual fingers when looking at both hands. This may apply to both the patient's and the observer's fingers and is usually associated with *agraphia, acalculia,* and a failure to *discriminate between right and left.* This syndrome is produced by a lesion of the left angular gyrus.

The receptive forms of aphasia, so-called 'word-blindness' and 'word-deafness', may justly be regarded as special varieties of visual and auditory agnosia.

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II. THE SIGNS OF LOCAL LESIONS OF THE BRAIN

It is customary in text-books on nervous diseases to describe in a separate section the signs of local lesions of the brain. Since these are dealt with in connexion with anatomy and physiology, tumours and vascular lesions, to avoid reduplication they will not be repeated, but for the convenience of the reader references are here

given to the parts of the book in which are described the signs of local lesions in various situations.

12 THE CEREBRO-SPINAL FLUID

ANATOMY AND PHYSIOLOGY

Formation, Circulation, and Absorption.

Clinical and experimental observation has established that the
cerebro-spinal fluid is mainly formed by the choroid plexuses of the
cerebral ventricles. That formed by the plexuses of the lateral ven-
tricles passes through the foramina of Monro into the third ven-
tricle. Thence the fluid flows through the aqueduct of Sylvius into
the fourth ventricle, which it leaves by the two lateral foramina of
Luschka to reach the subarachnoid space. The subarachnoid space,
which lies between the arachnoid membrane externally and the pia
mater internally, constitutes a vessel which carries the fluid from
the cerebral ventricles *to its points of absorption.* The *inner surface*
of the arachnoid and the outer surface of the pia mater are covered
with flattened mesothelial cells and these also cover the numerous
trabeculae, which bridge the subarachnoid space, and the nerves
and blood-vessels which pass across it. The subarachnoid space is

deepest at the base of the brain and between the inferior surface of the cerebellum and the medulla. In these regions its expansions constitute the various cisterns, the largest of which is the cisterna magna beneath the cerebellum.

The subarachnoid space extends superficially over the whole surface of the brain and spinal cord. It is also prolonged into the substance of the nervous system by means of extensions which are known as the perivascular spaces. Every blood-vessel entering or leaving the nervous system must pass across the subarachnoid space. In so doing it carries with it into the nervous system a sleeve of arachnoid immediately surrounding the vessel and a sleeve of pia mater more externally. Between the two lies the extension of the subarachnoid space, which is known as the perivascular space and which subdivides on each division of the vessel to terminate in continuity with the tissue spaces around the nerve-cells and fibres. It is probable that products of metabolism and cell-containing inflammatory exudates pass from the perivascular spaces to mingle with the cerebro-spinal fluid in the subarachnoid space, and it is the perivascular spaces which are seen to form cuffs round the vessels packed with inflammatory cells in microscopic sections taken from the nervous system in infective conditions such as syphilis, encephalitis lethargica, and poliomyelitis.

The cerebro-spinal fluid of the subarachnoid space probably receives a contribution from the perivascular spaces, and possibly also from the lymphatics of the cranial and other peripheral nerves. After bathing the surface of the spinal cord and the base of the brain it passes upwards over the convexity of the hemispheres, to be absorbed into the intracranial venous sinuses. The bulk of the evidence shows that absorption takes place through the microscopic arachnoid villi, which are minute projections of the subarachnoid space into the lumen of the sinuses. An alternative view accounts for the absorption of part or the whole of the fluid into the cerebral capillaries which are reached through the perivascular spaces.

CHEMICAL COMPOSITION OF THE CEREBRO-SPINAL FLUID

The following table, based upon the investigations of Fremont-Smith and Cohen, shows the principal differences in chemical composition between the cerebro-spinal fluid and the blood plasma. These two fluids, however, possess the same osmotic pressure as determined by depression of freezing-point, and Mestrezat put forward the view that they were in osmotic equilibrium, the higher chloride content of the cerebro-spinal fluid compensating for the much higher content of proteins in the blood plasma. These facts support the view that the cerebro-spinal fluid is formed by a process of dialysis

in which the cells of the choroid plexuses act as a semipermeable *membrane which is penetrable by electrolytes and not by non-electrolytes*. The absorption of the fluid has been regarded as a simple process of filtration.

Comparison of Blood Plasma and Cerebro-spinal Fluid.

	Blood Plasma	Cerebro-spinal Fluid.
Group 1 (Substances normally present in greater quantity in the plasma than in the fluid.)	Protein, 6–7 per cent.	Ventricular, 5–15 mg per cent.
		Cisternal, 15–25 mg. per cent.
		Lumbar, 15–40 mg. per cent.
	Inorganic phosphorus, 2–4 mg. per cent.	1·25–2 mg. per cent.
	Uric acid, 2–4 mg. per cent.	Trace.
	Cholesterol, 150 mg. per cent.	Trace.
	Calcium, 10 mg. per cent.	5–6 mg per cent.
	Sulphates, 4 mg. per cent.	1 mg. per cent.
	Glucose, 100 mg. per cent.	50–80 mg. per cent.
Group 2 (Substances normally present in greater quantity in the fluid than in the plasma)	Chlorine (as NaCl), 560–620 mg. per cent.	725–750 mg. per cent.
Group 3 (Substances approximately equally distributed between plasma and fluid.)	Sodium, potassium, CO_2, urea, lactic acid.	
Group 4 (Substances which do not pass from the plasma to the fluid except in minute traces)	Fibrinogen, iodides, salicylates, nitrates, lipoids, bile pigments, organic arsenic, most ferments, immune bodies.	

Volume and Rate of Formation.

The volume of the cerebro-spinal fluid in adults is normally about 130 c c Its rate of formation can only be estimated by artificial methods, the accuracy of which is doubtful. It is probable that the total volume is completely replaced several times a day.

Functions of Cerebro-spinal Fluid.

Many functions have been attributed to the cerebro-spinal fluid though most of them are somewhat speculative. There is no doubt, however, about its importance mechanically in protecting the nervous system from jars and shocks. Probably also it acts as a

regulator of the intracranial pressure and as a support to the venous sinuses in postures in which the intracranial venous pressure is raised. It is likely that it plays a part in the nutrition and metabolism of the nervous system, though this aspect of its functions is little understood.

Methods of Obtaining Cerebro-spinal Fluid

To obtain cerebro-spinal fluid for examination it is necessary to puncture either the cerebral ventricles or the subarachnoid space, which may be reached most easily either in the cisterna magna or in the lumbar cul-de-sac, where it extends beyond the lower end of the spinal cord.

Ventricle Puncture

Indications for Ventricle Puncture.

The following are the principal indications for ventricle puncture: (1) the relief of increased intracranial pressure before operation for intracranial tumour, (2) the injection of air into the ventricles for ventriculography for the diagnosis of hydrocephalus or intracranial tumour; (3) the injection of dyes into the ventricles for the diagnosis of hydrocephalus; (4) the injection of immune sera, especially in meningococcal meningitis, (5) for comparison of the pressure or chemical composition of the fluid in the two lateral ventricles or of the ventricular and spinal fluids; (6) in rare cases to obtain fluid for examination when there is a contra-indication to both cistern and lumbar puncture. The first and second are the purposes for which ventricle puncture is most frequently carried out.

Method of Ventricle Puncture.

In the infant, before closure of the anterior fontanelle, ventricle puncture is a simple matter. After the skin over the fontanelle has been shaved, cleaned with alcohol and ether, and painted with iodine, a small lumbar puncture needle, which has been sterilized, is introduced near the outer angle of the fontanelle, about 1 cm. from the middle line to avoid the superior longitudinal sinus. The needle is passed downwards and slightly outwards and should reach the lateral ventricle in a normal infant at a depth of between 3 and 5 cm. In internal hydrocephalus the ventricles are so much distended that they may be encountered at a depth of only 1 cm. In this condition the fronto-parietal suture is usually open and the ventricle may be tapped through this.

In the adult ventricle puncture involves a preliminary penetration of the skull.

A sufficient area of the patient's scalp having been shaved, the

skin is sterilized in the usual way. The patient is placed on his back on the operating table and points marked from 1 to 2 in. above the superior curved line of the occipital bone and 1 in. from the middle line on each side. The subcutaneous tissues in these regions are infiltrated with novocain and a small incision is made in the skin. The bone is bored and drilled with a burr until the dura is exposed. A small incision is made in the dura and a brain needle is introduced and passed vertically downwards. The lateral ventricle should normally be encountered at a depth of 5 cm.

SUBOCCIPITAL PUNCTURE

The cisterna magna, which is penetrated in suboccipital puncture, is a dilatation of the subarachnoid space lying between the inferior surface of the cerebellum above, the posterior surface of the medulla in front, and the dura mater covering the posterior occipito-atlantal ligament below and behind.

Indications and Contra-indications for Suboccipital Puncture.

The principal indications for suboccipital puncture are: (1) to obtain cerebro-spinal fluid for examination when lumbar puncture is for some reason, for example, on account of deformity of the spine, impossible: (2) for comparison of the composition or pressure of the cisternal and lumbar fluids; (3) for the injection of lipiodol in the radiographic investigation of blockage of the spinal subarachnoid space; (4) for the introduction of immune sera, for example, anti-meningococcal serum or salvarsanized serum. Suboccipital puncture should never be carried out when there is reason to suspect a tumour or abscess in the posterior fossa, when there is a marked rise of intracranial pressure, or when the cisterna magna is likely to be obliterated by inflammatory adhesions.

Method of Suboccipital Puncture.

The patient is prepared by shaving the scalp up to a horizontal line at the level of the external occipital protuberance. The skin is then cleaned with alcohol and ether and painted with iodine. The patient should be seated and his head is held by an assistant with both hands and well flexed. The operator places the tip of the forefinger of his left hand upon the spinous process of the second cervical vertebra, which is the highest palpable spinous process. A spot half an inch above this point is anaesthetized with ethyl chloride or with a 1 per cent. solution of novocain. A lumbar puncture needle with the stylet in position is then inserted at this point and passed forwards in a plane which passes through the point of introduction, the middle of the external auditory meatus, and the nasion. At a

depth of about 3 cm. the point of the needle will encounter the posterior occipito-atlantal ligament, which offers considerable resistance. On gently introducing it a further ½ cm. it should penetrate the cisterna magna, and on withdrawal of the stylet cerebro-spinal fluid usually drips from the needle. Often, however, although the point of the needle is in the cistern, there is no flow of fluid. This may be promoted by exerting gentle suction with a syringe inserted into the butt of the needle. The medulla lies at a depth of about 3 cm. in front of the posterior occipito-atlantal ligament. With care, therefore, there is no risk that the point of the needle will enter the medulla. It should not, however, be introduced more than 6 cm. from the surface of the skin. If the operator is unaccustomed to cistern puncture it is often rendered easier by directing the point of the needle slightly above the plane described, so that it comes into contact with the occipital bone. It is then slightly depressed to pass through the ligament. After withdrawal of the needle the point of puncture can be closed with collodion. Headache may follow suboccipital puncture. Its prophylaxis and treatment are the same as those described below for lumbar puncture.

LUMBAR PUNCTURE

Lumbar puncture is the simplest method of obtaining access to the subarachnoid space and is so frequently used that every practitioner of medicine should be capable of carrying it out. The spinal cord terminates at the lower border of the first lumbar vertebra in the adult, and at a slightly lower level in the child. The arachnoid is continued downwards below the termination of the spinal cord as far as the second sacral vertebra, and forms a lumbar cul-de-sac of the subarachnoid space normally containing cerebro-spinal fluid and crossed by the roots of the cauda equina. A needle can be introduced into this space without risk of injury to the spinal cord.

Indications and Contra-indications.

Lumbar puncture is carried out for the following purposes: (1) to obtain cerebro-spinal fluid for cytological, chemical, and other investigations and to estimate its pressure; (2) in the relief of intracranial pressure and the removal of toxic, inflammatory, or other irritative substances in the cerebro-spinal fluid, in the various forms of encephalitis and meningitis, intracranial haemorrhage, external hydrocephalus, uraemia, eclampsia, &c.; (3) to introduce into the subarachnoid space therapeutic substances such as immune sera or antiseptic drugs or local anaesthetics; (4) to introduce into the subarachnoid space air for radiographic purposes—encephalography or for treatment; (5) to introduce lipiodol for radiography.

I

There are few contra-indications to lumbar puncture. In the presence of greatly increased intracranial pressure, especially when there is reason to suspect a tumour in the posterior fossa of the skull, sudden withdrawal of fluid from the spinal canal may cause herniation of the medulla into the foramen magnum—the 'cerebellar pressure cone'—with fatal results. In such cases ventricle puncture is the only safe method of obtaining cerebro-spinal fluid. The presence of infection in the lumbar region is a contra-indication to lumbar puncture, owing to the risk of infecting the spinal canal. The presence of marked spinal deformity in the dorsal or lumbar regions may render lumbar puncture difficult or impossible.

The Needle.

There are a number of patterns of lumbar puncture needle. Their gauge ranges from 17 to 19 ; a good length is 8 cm. Harris's needles for trigeminal injection made by Messrs. Weirs are excellent. The Dattner needle consists of a fine inner needle, 25, within an outer one, 20, the use of which is described below. A needle of large diameter may be required in cases of meningitis when pus containing flakes of fibrin is to be withdrawn. The Barker is a longer and stouter needle suitable for these purposes. The needle is best sterilized by being washed with boiled water and surgical spirit after use and kept in surgical spirit to which a small quantity of lysol has been added It is washed with sterile water before being used again.

Method of Puncture.

Lumbar puncture may be performed with the patient either sitting or lying on one side. As many patients cannot sit up, it is best to accustom oneself to performing the operation with the patient lying on his left side. In either position the most important point is to secure the greatest possible degree of flexion of the lumbar spine If the patient is conscious and co-operative he should be asked to bend his legs until his knees approach his chin and then to clasp his hands beneath his knees, or an assistant can aid flexion of the spine by applying pressure with one hand behind the neck and the other beneath the knees. When the patient is in position the next step is to find the landmarks. A line joining the highest points of the iliac crests, which may be marked with a swab dipped in iodine, usually passes between the third and fourth lumbar spinous processes, and the puncture can be performed either at this point or between the fourth and fifth spines. The skin is now cleaned with alcohol and ether and painted with iodine. A local anaesthetic is not essential, but renders the proceeding more comfortable for the patient. The skin may be anaesthetized with ethyl chloride, or with 1 per cent.

where puncture of a vein is the commonest cause of blood in the fluid. The stylet should be passed into the needle again to remove any possible obstruction and the depth of the point varied. If no fluid comes, the needle should be withdrawn and reinserted either in the same interspace or in the one above or below. A genuine dry tap, when the point of the needle is actually in the subarachnoid space, may occur when the spinal subarachnoid space is blocked at a higher level and hence the pressure of the fluid in the lumbar sac is low, or when the lumbar itself is filled by a neoplasm or by a congenital abnormality, as in spina bifida.

Sequels of Lumbar Puncture.

The only common sequel of lumbar puncture is headache, which comes on after a few hours, is throbbing in character, and may be associated with nausea, vomiting, giddiness, and pain in the neck and back In severe cases it is literally prostrating, being much intensified by sitting up, and lasting for days or even exceptionally for weeks. It is most likely to occur when a normal fluid is withdrawn and is very rare in syphilitic patients. It is due to lowered intracranial tension produced by a continued leakage of cerebrospinal fluid through the puncture wound in the theca. When the Dattner needle is used, headaches occur in only 3 per cent. of patients who are punctured as out-patients and allowed to go home (Erskine and Johnson, 1938). With an ordinary needle certain precautions will do much to prevent the development of 'lumbar puncture headache'. The needle used should be small in calibre, and introduced with the cutting edges in the sagittal plane. The minimal amount of fluid should be withdrawn; in any case not more than 10 c c, unless the object of the puncture is to reduce the intracranial pressure. The patient, who should be kept in bed for twenty-four hours after the puncture, should be without a pillow for several hours and the foot of the bed may be raised. If in spite of these precautions headache develops, treatment is directed to raising the intracranial pressure by promoting the formation of cerebrospinal fluid This is best accomplished by the ingestion of water in large quantities. A jug which is kept filled with water should stand by the bed and the patient should be supplied with a rubber tube through which he can drink without raising his head. He should drink a gallon of water in twenty-four hours. Alternatively 50 c.c. of distilled water can be injected intravenously. A subcutaneous injection of $\frac{1}{2}$ c c of pituitrin is sometimes effective, but is less likely to succeed than the water treatment. Analgesics may be given as required.

Lumbar puncture occasionally causes an intensification of symp-

toms of the disease from which the patient is suffering. Root pains, if present, may be intensified, and this is especially liable to occur in the presence of a lesion compressing the spinal cord, any of the symptoms of which may be exacerbated by the alterations of pressure induced by the withdrawal of fluid. In disseminated sclerosis relapses have sometimes been attributed to lumbar puncture, and in this disease the operation has sometimes appeared to precipitate a terminal acute encephalo-myelitis. These events, however, are too rare to operate as contra-indications. The risks attendant upon lumbar puncture when the intracranial pressure is greatly increased, especially when there is a tumour in the posterior fossa, have already been described. Meningitis following lumbar puncture is almost unknown.

ROUTINE EXAMINATION OF THE CEREBRO-SPINAL FLUID

Pressure.

Method of Determination. The pressure of the cerebro-spinal fluid is best determined by means of a simple manometer. A graduated glass tube is attached to the lumbar puncture needle and the observer reads the height to which the fluid ascends in the tube. The instrument designed by Greenfield consists of a lumbar puncture needle with a two-way stopcock which permits fluid to be withdrawn while the manometer remains attached. A glass tube 30 cm. long is attached to the needle by a small piece of rubber tubing. To estimate pressures of more than 300 mm. it is necessary to connect a second length of tubing. For routine purposes the pressure is determined with the patient lying on the left side, and it is important to see that the head is supported at the same level as the lumbar spine. Lumbar puncture having been performed in the usual way, the tap is turned so that the fluid rises in the manometer. At this point the patient should be allowed to straighten his spine and should be directed to relax his muscles and breathe quietly and regularly, as muscular tension and holding the breath raise the pressure. Pressure is measured in millimetres of cerebro-spinal fluid and normally shows oscillations corresponding to respiration and finer variations synchronous with the arterial pulse. The normal pressure of the cerebro-spinal fluid in adults in the horizontal position is 60–150 mm. of fluid. According to Levinson it is lower in children, in whom it is normally from 45–90 mm. of fluid. In adults in the sitting posture the normal pressure is from 200 to 250 mm. of fluid, but it should be noted that this is usually lower than the height of the vertex above the needle. Hence in the sitting posture the pressure in the ventricles and cisterna magna may be negative.

A less accurate but more portable manometer consists of a fine rubber tube 20 inches long to one end of which 3 inches of glass tube is attached and to the other end a spigot which fits the needle. A rule or tape measure is used to measure the height of the fluid level in the glass tube above the lumbar puncture needle.

Pathological Variations of Pressure. An abnormally high cerebrospinal fluid pressure is found in cases of intracranial tumour and haemorrhage, hydrocephalus, intracranial sinus thrombosis, meningism, and the various forms of meningitis and encephalitis, including the more acute forms of syphilitic meningitis and general paralysis. The pressure may also be raised in uraemia. In intracranial tumour the pressure may be as high as 500–1000 mm. of fluid.

A subnormal pressure is sometimes a sequel of head injury. It is also encountered in conditions in which the lumbar subarachnoid space is cut off from communication with the cerebral subarachnoid space. This is most commonly met with in cases of spinal subarachnoid block due to spinal tumour or localized spinal meningitis. It may also occur when a block exists at the region of the foramen magnum as a result of a tumour in this situation or of meningeal adhesions following meningitis. The cerebro-spinal fluid pressure may also be abnormally low if a second lumbar puncture is performed within a few days after a previous one.

Ayala's Index. The withdrawal of fluid by lumbar puncture naturally leads to a fall in the pressure of the remainder. Diagnostic value has been attributed to a correlation between the volume of fluid withdrawn and the resulting fall of pressure. Ayala's index is obtained by the formula $\dfrac{Q \times F}{I}$, Q being the number of c.c. of fluid removed, I the original pressure, and F the final pressure. In cases in which the diagnosis lies between intracranial tumour and communicating hydrocephalus an index of below 5·5 is in favour of tumour, while one above 6·5 is in favour of 'communicating hydrocephalus'.

Queckenstedt's Test. Normally if one compresses the jugular veins of a patient during lumbar puncture there is an immediate and rapid rise in the pressure of the cerebro-spinal fluid which quickly reaches 300 mm. of fluid and almost as rapidly falls to normal when the veins are no longer compressed. The effect of compressing the veins is to cause a temporary congestion of the intracranial venous sinuses and hence to raise the pressure of the cerebro-spinal fluid. The communication of this raised pressure to the manometer attached to the lumbar puncture needle depends upon the patency of the subarachnoid space between the cranial cavity and the lumbar sac. In cases of obstruction of the subarachnoid space in the region of the foramen magnum

or within the spinal canal the rise of pressure normally produced by jugular compression is either absent or slight in extent and slow in appearing, according to whether the block is complete or incomplete. In such cases also the normal variations in pressure due to respiration and the arterial pulse are also diminished or absent, but compression of the abdomen may cause an exaggerated rise of pressure.

Compression of either jugular vein separately may yield valuable evidence of thrombosis of the lateral sinus, there being no rise of pressure in the fluid when the jugular on the affected side is compressed.

Naked-eye Appearance.

Turbidity. The normal cerebro-spinal fluid is clear and colourless and resembles water. Turbidity, when present, is usually due to an excess of polymorphonuclear cells. In acute meningitis these are often present in such numbers that a deposit of pus forms at the bottom of the tube and the supernatant fluid may be yellow. It is very rare for an excess of lymphocytes to cause turbidity, but this may occasionally be due to micro-organisms.

Fibrin Clot. The development of a clot of fibrin in a specimen of fluid implies the presence of fibrinogen and of fibrin ferment. Such a clot may occur either in a fluid of which the protein content is only slightly raised or in the highly albuminous fluids characteristic of spinal subarachnoid block, and sometimes occurring in polyneuritis. In the former case the clot takes the form of a faint 'cobweb' which takes from twelve to twenty-four hours to appear. It is most frequently seen in tuberculous meningitis, but also occurs occasionally in other forms of meningitis and has been described in syphilitic meningitis and in poliomyelitis. The clot which forms in highly albuminous fluids may solidify the whole specimen. In such cases clotting may be precipitated by the addition of fibrin ferment in the shape of a drop of fresh blood.

Blood. Blood may be present in the cerebro-spinal fluid, either as an accidental result of injury to an intrathecal vein by the lumbar puncture needle, or as the product of pre-existing haemorrhage into the subarachnoid space. This distinction is obviously of great importance. When a vein is injured at lumbar puncture the specimen of fluid collected in the first tube is often blood-stained, but the second usually shows no visible blood, whereas after subarachnoid haemorrhage both specimens are uniformly blood-stained. Further, in the former case if the red cells are given time to settle, the supernatant fluid is seen to be colourless, whereas within a few hours of subarachnoid haemorrhage the supernatant fluid shows a yellow coloration. In practice there is seldom any difficulty in distinguishing

the accidental contamination of the specimen with blood from subarachnoid haemorrhage. *Subarachnoid haemorrhage* is usually due either to head injury, or to the rupture of an intracranial aneurysm into the subarachnoid space, or to the bursting of an intracerebral haemorrhage either into the ventricular system or into the subarachnoid space. It may occasionally result from the leakage of blood from an intracranial tumour, especially from an angioma, and in rare cases an intense 'haemorrhagic' form of encephalitis may lead to the presence of small amounts of blood in the cerebro-spinal fluid. Following subarachnoid haemorrhage the yellow coloration of the fluid appears in a few hours and reaches its greatest intensity at the end of about a week. It has usually disappeared after from fourteen to twenty-one days. The red cells disappear from the fluid in two or three days. The presence of blood in contact with the leptomeninges excites a cellular reaction, and the fluid therefore usually contains a moderate excess of cells. As a rule these are all mononuclear, but occasionally polymorphonuclear cells are found.

Xanthochromia. Xanthochromia, or yellow coloration of the cerebro-spinal fluid, is found, as just described, after subarachnoid haemorrhage and also when pus is present in considerable amount in the fluid. Xanthochromic fluid is also occasionally found in cases of intracranial tumour, especially when the tumour is near the ventricular system, and sometimes in the case of tumours of the eighth nerve. It is also characteristic of obstruction of the spinal subarachnoid space and may also be seen in fluid from above a tumour of the cauda equina and sometimes in polyneuritis. A slight yellow coloration of the fluid may be present in cases of jaundice of long standing.

Cytological and Chemical Abnormalities.

Since this is a text-book of clinical neurology, methods of carrying out cell counts and chemical investigations on the cerebro-spinal fluid will not be described in more detail than is necessary for a discussion of their interpretation. Those who wish to acquaint themselves with the technique of these examinations are referred to text-books on the cerebro-spinal fluid (see list of references).

Cells. The normal cerebro-spinal fluid contains a small number of cells. These are lymphocytes or large mononuclear cells and should not exceed in number three per cubic millimetre. In pathological states a greater variety of cells may be present and these may occur in very large numbers. Those most frequently encountered are lymphocytes and large mononuclear cells and polymorphonuclear cells. Less frequently eosinophils, plasma cells, macrophages, and compound granular corpuscles and fibroblasts are found. Tumour cells are rare but when present are of great diagnostic importance.

Yeasts, actinomycotic granules, echinococci, and cysticerci have been observed in cases of infection of the nervous system with these organisms.

Significance of Cell Content. Certain generalizations may be made with regard to the presence and numbers of different types of cell in the fluid. The majority of cells are probably derived from the meninges, though some may take origin within the nerve tissue and pass into the subarachnoid space from the perivascular spaces. In general a pleocytosis, or excess of cells in the spinal fluid, indicates meningeal irritation, though this does not necessarily imply the presence of meningeal infection. Whether the cellular increase is polymorphonuclear or mononuclear depends partly upon the acuteness of the pathological process and partly upon the nature of the infecting organism. A predominantly polymorphonuclear count is usually found in acute infections and in acute exacerbations of chronic infections, while a mononuclear count is characteristic of chronic infections. But while pyogenic organisms excite a mainly polymorphonuclear leucocytosis except in their most chronic stages, a mononuclear pleocytosis is characteristic of infection with neurotropic viruses, though polymorphonuclear cells are sometimes present when the infection is most acute. We thus encounter predominantly polymorphonuclear, predominantly mononuclear, and mixed cell counts.

A predominantly polymorphonuclear pleocytosis is found in meningitis due to pyogenic organisms, including the meningococcus, staphylococcus, streptococcus, pneumococcus, bacillus coli, bacillus typhosus, and Pfeiffer's bacillus. In these conditions the polymorphonuclear cells are usually present in very large numbers. A very acute syphilitic meningitis may also excite a polymorphonuclear reaction in which the cells may number several thousands per cubic millimetre. Mononuclear pleocytosis rarely exceeds 200 cells per c.mm. and more commonly lies between 10 and 50 cells per c.mm. It is characteristic of syphilis of the nervous system, encephalitis lethargica, disseminated sclerosis, poliomyelitis (after the first few days of the infection), herpes zoster, acute lymphocytic chorio-meningitis, and some cases of tubercular meningitis. It may also be present in mumps and has been described in whooping cough, malaria, trypanosomiasis, and spirochaetosis ictero-haemorrhagica. Cerebral tumour may cause a slight mononuclear pleocytosis, especially when the tumour is in contact with the meninges. So also may cerebral abscess, intracranial sinus thrombosis, and subarachnoid haemorrhage. The mixed type of pleocytosis, in which polymorphonuclear and mononuclear cells are present in approximately equal numbers, is found in cerebral abscess, in which case the number of cells is often small,

and in cases of infection of the bones of the skull in the neighbourhood of the meninges. A mixed cell count is also present in many cases of tuberculous meningitis, in poliomyelitis, during the first few days, and in the more acute forms of syphilitic meningitis.

Protein.

The total protein content of the normal cerebro-spinal fluid is from 0 02 to 0 04 per cent. This consists of albumin and globulin in a ratio of 8 to 1 (Hewitt). Increase of the protein of the fluid is extremely common. A moderate increase, usually to below 0·1 per cent. is usually found in inflammatory diseases of the nervous tissue and meninges, such as the various forms of meningitis, encephalitis, poliomyelitis, disseminated sclerosis, and syphilis of the nervous system. Intracranial tumour and cerebral arteriosclerosis may also cause a rise of protein content. A marked rise is less common.

Froin originally described the syndrome which is known by his name and in which a high protein content of fluid was associated with xanthochromia, massive coagulation, and pleocytosis. Froin's cases were examples of obstruction of the spinal subarachnoid space, due to localized spinal meningitis, which was responsible for the pleocytosis. The essential part of the syndrome is now known to be the great excess of protein, and Greenfield and Carmichael propose that the term Froin's syndrome should be applied only to fluids which contain 0·5 per cent. of protein or more, and which are not frankly purulent. Thus defined it occurs, according to these authors, in three classes of disease: (1) chronic, especially syphilitic, meningitis, and more rarely acute and subacute meningitis; (2) obstruction of the spinal subarachnoid space, due to tumour of the cord or its envelopes, spinal caries, and epidural abscess, whether tuberculous or staphylococcal; (3) polyneuritis, Landry's paralysis. It may also occur in fluid withdrawn above the level of a tumour of the cauda equina. The characteristic changes in the spinal fluid which occur in obstruction of the spinal subarachnoid space are attributable to several anatomical factors. Spinal block cuts off the fluid below the obstruction from the normal course of circulation and absorption. Compression of the spinal veins by a tumour or similar lesion causes chronic venous congestion of the cord below the level of the obstruction, since the venous drainage of the cord is from below upwards in the longitudinal veins which have few anastomoses. The spinal arteries on the other hand, although they run longitudinally, anastomose freely with the radicular arteries, which enter the spinal canal through the intervertebral foramina. Further, blood plasma may pass into the spinal fluid from the blood-vessels of a tumour, or as inflammatory exudate when the obstructive lesion is a meningitis.

The Albumin–Globulin Ratio.

Several reactions designed to demonstrate an excess of globulin in the cerebro-spinal fluid are in common use. In the *Nonne-Apelt reaction* ammonium sulphate is the reagent employed. A positive reaction ranges from a slight opalescence to actual precipitation of the globulin. In *Noguchi's reaction* the globulin if present in excess is precipitated by butyric acid. In *Pandy's* a solution of carbolic acid is used and positive reactions range from opalescence to milky turbidity. Similar positive reactions are obtained in *Weichbrodt's reaction* with a solution of mercuric chloride. These reactions are not quantitative. Pandy's reaction is the most sensitive, and may yield a weakly positive result with normal fluids.

In normal fluids the greater part of the globulin present is pseudo-globulin. In pathological fluids an increase of globulin is usually associated with an increase in albumin, and the increase of the former is often proportionately greater than that of the latter. Euglobulin shows a much greater increase than pseudoglobulin, especially in general paralysis. In normal fluids the albumin-globulin ratio is 8 to 1, in tabes, meningitis, and encephalitis lethargica it may be 3 to 1, in general paralysis it averages 1·3 to 1 (Hewitt). A low albumin-globulin ratio occurs also in spinal subarachnoid block.

Chlorides.

The chlorides are the only chemical constituent of the cerebro-spinal fluid which is maintained at a higher concentration than in the blood. The normal chloride content of the fluid is 720 to 750 mg. per 100 c.c. estimated as sodium chloride. In purulent meningitis this figure is reduced to an average of from 650 to 680 mg. per 100 c.c. The reduction is much greater in tuberculous meningitis, in which condition Fremont-Smith and his collaborators obtained an average reading of 610 mg. per 100 c.c. and a minimum of 520 mg. In the early stages of tuberculous meningitis the reduction is less marked. The chloride content of the fluid is thus of diagnostic value in distinguishing tuberculous meningitis both from conditions such as poliomyelitis in which the chloride content of the fluid is normal and also from other conditions of meningeal inflammation in which the fall is less marked. Greenfield and Carmichael consider that a chloride content of less than 580 mg. per 100 c.c. *in the presence of other indications of meningeal inflammation* in the fluid is pathognomonic of tuberculous meningitis. The fall in chlorides in the cerebro spinal fluid in the various forms of meningitis appears to be parallel with, and is probably secondary to, the fall in the chlorides of the blood plasma. When the chloride content of the blood plasma

varies from normal a corresponding change occurs in the chlorides of the fluid Hence we find the chloride content of the fluid above normal in many cases of nephritis, especially in the stage of uraemia and below normal in meningism.

Glucose.

The normal glucose content of the cerebro-spinal fluid is somewhat lower than that of the blood and lies between 50 and 85 mg. per 100 c c Diminution of the glucose content of the fluid is found in meningitis and is more marked in meningitis due to pyogenic organisms than in tuberculous meningitis. It is probable that glucose in the fluid is consumed by the infecting organisms. A rise in the glucose content of the fluid parallel to that obtaining in the blood is found in diabetes.

Colloidal Reactions.

Lange's Colloidal Gold Reaction. Lange's colloidal gold reaction is often of great diagnostic value, although its theoretical basis is incompletely understood. It is based upon the observation that the cerebro-spinal fluid in certain pathological states possesses the property of precipitating a preparation of colloidal gold and that the degree of precipitation varies according to the concentration of cerebro-spinal fluid used.

In carrying out the test ten test-tubes are employed, each of which contains the same amount of the colloidal gold solution. Cerebro-spinal fluid is then added in such a way that in the first tube it is present in a concentration of 1 in 10 and in each subsequent tube this concentration is progressively reduced by one half. The result is a series of ten tubes each containing the same amount of colloidal gold solution, but containing concentrations of cerebro spinal fluid ranging from 1 in 10 to 1 in 5120. The unchanged colloidal gold solution is cherry red in colour, and this colour changes in proportion to the degree of precipitation, through purple and blue to complete de-colorization of the supernatant fluid with a bluish precipitate. These changes are numerically expressed, 0 signifying no change and the figures 1 to 5 denoting progressive degrees of alteration. In reading the result of the test the tube containing the highest concentration of cerebro-spinal fluid is placed on the left and the concentration diminishes in the series from the left to the right.

The following types of colloidal curve may be encountered:

(1) Normal fluids cause no precipitation, except possibly to the slightest extent in the middle of the curve and are thus reported as (0000000000) or (0001110000).

(2) The 'paretic' curve In this type of curve complete precipita-

tion occurs in the first four or five tubes and none in the last two or three. A typical series would be 5555321000. The 'paretic' curve is so called from its constancy in general paralysis. It may be present in meningovascular syphilis and in tabes. It is also found in some 50 per cent. of cases of disseminated sclerosis.

(3) The luetic or tabetic curve. This is represented by the figures 1233210000 and is the type of curve usually encountered in tabes and meningovascular syphilis.

(4) The meningitic curve shows a plateau farther to the right than the preceding and is represented by the figures 0012344310. This type of curve is that usually found in meningitis.

The principal value of the colloidal gold curve lies in its assistance in differentiating general paralysis from other types of neurosyphilis and in the support which it sometimes yields for a diagnosis of disseminated sclerosis. A paretic curve is always found in untreated cases of general paralysis, and though it is sometimes present in other forms of neurosyphilis it is much more readily altered by treatment in the latter than in the former. In a suspected case of disseminated sclerosis the presence of a paretic curve in the cerebro-spinal fluid in association with a negative Wassermann reaction is to be taken as confirmatory evidence of the diagnosis.

The explanation of the varying degree of precipitation of the colloidal gold solution by different dilutions of the cerebro-spinal fluid in pathological states is still somewhat obscure, but it is probable that it ultimately depends upon the relative concentration of albumin and globulins in the fluid.

Other colloidal preparations, for example, mastic, benzoin, gamboge, and collargol, have been employed, but it is doubtful if they possess any advantages over the colloidal gold test, which appears to be more sensitive.

Serological Reactions.

The Wassermann and Meinicke reactions in the cerebro-spinal fluid are discussed in the section on syphilis.

Bacteriological Examination.

In cases of infection of the nervous system and the meninges with pyogenic organisms and with the tubercle bacillus a bacteriological examination of the cerebro-spinal fluid may be necessary, especially to determine the causal organism in meningitis.

When dealing with a fluid which is frankly purulent it is sufficient to make a film with a platinum loop and to stain it in the usual way. When there is no visible pus and in suspected cases of tuberculous meningitis it is advisable to centrifuge the fluid before examining it.

Cultures should also be made, both for the further identification of an organism which is seen in the film and also because when the film yields a negative result an organism can sometimes be isolated by culturing.

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13. HISTORY AND EXAMINATION

THE HISTORY OF THE ILLNESS

General Considerations.

In the diagnosis of nervous diseases the history of the patient's illness is often of greater importance than the discovery of his abnormal physical signs. The group of physical signs may be common to several disorders, and only an accurate knowledge of their mode of development may enable the correct diagnosis to be made. The history obtained from the patient should always be supplemented, if possible, by an account of his illness given by a relative or by some one who knows him well. This is essential when the patient suffers from mental impairment and also when his complaint includes attacks in which he loses consciousness, but it is always desirable, since a relative or friend will often remember an important point which the patient himself has forgotten to mention.

First note the patient's name and address, age, and exact details of his occupation. The last named is often of importance as a source of exposure to injury or to toxic substances, for example lead. Ascertain if he is right-handed.

It is well to begin by asking the patient of what he complains and when he was last in normal health, in this way fixing, at least provisionally, the date of onset of his symptoms. After this he should be allowed to relate the story of his illness as far as possible without

interruption, questions being put to him afterwards to expand his statements and to elicit additional information. In the case of all symptoms it is important to ascertain not only the date but also the mode of onset, whether sudden, rapid, or gradual, whether the symptom since its first appearance has fluctuated in intensity and whether the patient's condition is improving, stationary, or deteriorating at the time of examination.

History of Present Illness.

Inquiry should always be made with regard to the following symptoms, whether or not the patient mentions them spontaneously:

Mental State. The patient's mental history should be ascertained, not only as far as possible from himself, but also from relatives or friends, on the lines laid down below for the examination of his mental condition.

Sleep. Has he suffered from disturbances of sleep, either from paroxysmal or persistent sleepiness or from insomnia?

Speech. Has he had difficulty in speaking? If so, of what nature? Has he been able to understand what is said to him and to read? Has his writing been affected?

Convulsions. Has he suffered from convulsions or from fainting attacks? If so, further inquiries should be made (see p. 855).

Headache. Has he suffered from headache? If so, further inquiries should be made as described on p. 276.

Special Senses. Has he had hallucinations of smell or taste or noticed an impairment of these senses? Has he had visual hallucinations? If so, what has been their character and distribution in the visual fields? Has there been any visual impairment: if so, of one or both eyes? Has it been transitory or progressive? Has he had double vision? If so, has this been transitory or progressive and has he noticed this symptom when looking in any special direction? Is his hearing impaired? If so, is this unilateral or bilateral and is the deafness associated with tinnitus? Does he suffer from giddiness? If so, he should describe precisely its nature and state whether it is associated with a sense of rotation of himself or of his surroundings, and with deafness, tinnitus, or vomiting.

Movement and Sensibility. Does he complain of muscular weakness, of loss of control over the limbs or of involuntary movements, and if so, what is the distribution of these symptoms? Has his gait been abnormal, and if so, how? Has he tended to fall, and if so, in what direction? Has he had any spontaneous sensory disturbances, especially pain, numbness, or tingling? If so, further inquiries should be made, as described on p. 23.

The Sphincters and Reproductive Functions. Has there been any

disturbance of sphincter control? Has he experienced difficulty in holding or passing urine or faeces? Has he had polyuria? In the case of a man, is his sexual power normal for his age? In the case of a woman, has there been any abnormality in menstruation, especially amenorrhoea?

Nutrition. Is the weight stationary, diminishing, or increasing?

History of Previous Illnesses.

Inquiry as to previous illnesses should always include, in the case of a male patient, a specific inquiry as to venereal disease. A history of aural discharge or of tuberculosis may be important in relation to intracranial abscess or tuberculoma meningitis. A history of convulsions or of meningitis in childhood or of encephalitis lethargica may be significant in relation to a later illness. A history of 'influenza' should be amplified by details of the illness thus described Inquiry should always be made for a history of accidental injury, especially to the head and spine.

Personal Habits.

Inquiry should be made as to past residence abroad and also as to the amount of alcohol habitually consumed. If alcoholic excess is admitted, its amount and duration should be ascertained.

Family History.

The family history is often of great importance, since many diseases of the nervous system are hereditary. The patient should always be asked whether cases of nervous or mental disease have occurred among his relatives. If the patient is married, inquiry should be made as to the state of health of the spouse. Death of husband or wife from general paralysis or aneurysm may afford an important clue to a syphilitic disorder in a patient. For the same reason the number of children and the occurrence of miscarriages and stillbirths should be ascertained.

EXAMINATION OF THE PATIENT

Mental State.

Is the patient conscious or unconscious? If unconscious, can he be roused, and if so, when he is roused is his mental condition normal or abnormal? The following psychological investigations are of course applicable only to conscious patients.

Intellectual Functions.

Is the patient orientated in space and time? Does he recognize his surroundings and does he know the date? Is his memory normal, and, if impaired, is it better for remote than for recent events? Does

he fill gaps in his memory by confabulating, that is, by relating imaginary events? Retentiveness may be tested by asking the patient to repeat a series of digits—normally seven can be repeated—or retain a name, address, and flower for five minutes.

Does he suffer from delusions or hallucinations? A delusion is an erroneous belief which cannot be corrected by an appeal to reason and is not shared by others of the patient's education and station. An hallucination is a sensory impression occurring in the absence of a corresponding external stimulus. A patient may conceal both delusions and hallucinations. The latter may sometimes be suspected on account of his behaviour. For example, a patient who is subject to visual hallucinations may behave as though manipulating invisible objects, while one who is experiencing auditory hallucinations, for example voices, may adopt a listening attitude. Are the patient's powers of attention and concentration normal? Does he take normal care of his dress and appearance, or is he indifferent and dirty?

Emotional State.

Is the patient's emotional state normal? Is he excited or depressed? If excited, is his condition one of elation, that is, excitement associated with a sense of well-being, or of fear and anxiety? Apart from excitement, does he experience an abnormal sense of well-being—euphoria? Is he anxious and, if so, to what does he attribute his anxiety? Is he irritable? Is he emotionally indifferent and apathetic?

Speech and Articulation.

Are speech and articulation normal? If there is reason to suspect that the patient is suffering from aphasia, the appropriate tests must be carried out (see p. 98).

The Cranial Nerves.

Test the sense of smell for each nostril separately (see p. 134).
Test the visual acuity and visual fields (see pp. 52–4).
Examine the ocular fundi (see p. 135).
Are the pupils equal, central, and regular? Are they abnormally dilated or contracted? Test the reactions to light, both direct and consensual, of each eye separately and the reaction on accommodation-convergence.

Test the ocular movements, upwards and downwards and to either side, and ocular convergence. Is squint, diplopia, or nystagmus present? Note the size of the palpebral fissures. Does the patient exhibit ptosis or retraction of the upper lids? Is exophthalmos or enophthalmos present?

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Is there wasting of the temporal muscles and masseters? Test the jaw movements and the jaw jerk.

Examine sensibility to light touch, pin-prick, heat and cold, over the trigeminal area, and test the corneal reflexes.

Is the facial expression normal? Is there wasting of the facial muscles? Is the face the site of involuntary movements? Test the following voluntary movements—closure of the eyes, elevation of the eyebrows, frowning, retraction of the lips, pursing the lips, whistling Test emotional facial movements—smiling. In some cases of facial paralysis it is necessary to test the sense of taste (see p. 194).

Test the hearing, both air-conduction and bone-conduction. If hearing is defective, apply both Weber's and Rinne's tests (see p 175). In certain cases it may be necessary to test the vestibular reactions (see pp. 179–84).

Is the soft palate elevated normally on phonation? Test the palatal and pharyngeal reflexes.

Examine the movements of the vocal cords, if necessary.

Test the movements of the sternomastoids and trapezii.

Examine the tongue. Is it wasted? Is fibrillation present? Is it tremulous? Is it protruded normally?

Note the presence or absence of head retraction and test for cervical rigidity.

The Limbs and Trunk.

The following is a convenient routine for the examination of the limbs and trunk. Examine the upper limbs while the patient is lying down, then ask·him to sit up, or, if he is unable to do so, to turn on to one side, and examine the scapular muscles and the back; then ask him to lie down again and examine the front of the thorax and the abdomen, and finally the lower limbs. Sensibility as well as motor functions should first be examined in this order, but in many cases, especially when there is reason to suspect a lesion of the spinal cord, it may be convenient to review the sensibility of the body as a whole.

Muscular Power and Co-ordination. In examining the limbs note first their *posture* and the presence or absence of *muscular wasting* and *fibrillation*. Next note the presence or absence of *involuntary movements*, of which the following are those most commonly encountered. A tic is a co-ordinated, repetitive movement involving as a rule a number of muscles in their normal synergic relationships. Choreic movements are quasi-purposive, jerky, irregular, and non-repetitive, and are characterized by dissociation of normal muscular synergy. Athetosis consists of slow, writhing movements, which are most marked in the peripheral segments of the limbs. Tremor is a rhythmical movement at a joint, brought about by alternating

contractions of antagonistic groups of muscles. Myoclonus is a shock-like muscular contraction affecting part or the whole of the muscle independently of its antagonists. If involuntary movements are present, note their relationship to rest and voluntary movement.

Next examine *muscle-tone* by passive movement at the various joints and note the presence or absence of *muscular contractures*. Next test voluntary power by asking the patient to carry out against resistance the movements possible at the various joints, comparing successively the same movement on the two sides of the body. *Muscular co-ordination* is tested in the upper limbs by asking the patient to touch the tip of his nose with the tip of his forefinger, first with the eyes open and then with the eyes closed. He should also be asked to carry out alternating movements of flexion and extension of the fingers, or pronation and supination of the forearms simultaneously on both sides. When the patient is in bed, co-ordination of the lower limbs may be tested by asking him to place one heel on the opposite knee, or to raise the leg from the bed and touch the observer's finger with his toe.

Movements of the abdominal wall are tested by asking the patient to raise his head from the bed against resistance and noting by palpation the degree of contraction of the abdominal muscles and also whether displacement of the umbilicus occurs.

Sensibility. As a routine, the patient's appreciation of light touch, pin-prick, heat and cold, posture, passive movement, and vibration should be tested, attention being paid not only to defective sensibility but also to the presence of tenderness of the superficial and deep structures. In some cases additional tests may be needed (see p. 24). Since the spinal segmental areas run longitudinally along the long axis of the upper limbs, sensibility on the ulnar border should be compared with that on the radial border, either by applying successive stimuli transversely to the limb, or by dragging the stimulus, for example a pin, along the skin. On the trunk the segmental areas are distributed almost horizontally. Changes of sensibility are therefore best detected by moving the stimulus from below upwards or vice versa. In the lower limbs the sacral segmental areas, which are represented on the sole and the posterior aspect of the limb, should always be tested.

The Reflexes. The following reflexes should be examined as a routine: in the upper limbs, the supinator, biceps and triceps jerks; in the lower limbs, the knee and ankle jerks and the plantar reflexes; at the same time tests for patellar and ankle clonus should be carried out; on the trunk, the abdominal reflexes.

The Sphincters. Note the state of the sphincters and examine the abdomen for evidence of distension of the bladder.

Trophic Disturbances. Note the state of the patient's nutrition, especially the presence of wasting or excessive obesity and the condition of the external genitalia. Note the distribution of hair on the body, anomalies of sweating, and the presence or absence of cutaneous pigmentation and trophic lesions of the skin, nails, and joints

Examine the *scalp* and *skull* (see p. 234) and also the *spine*, noting the presence of deformity, rigidity, and tenderness in the latter.

Gait.

If the patient is well enough to leave his bed, observe whether he is able to stand without support with the feet together, and whether the steadiness of his stance is affected when he closes his eyes. Ask him to walk, if necessary with support, and note the presence of spasticity or ataxia of the lower limbs in walking. Slight disturbances of stance and gait may be detected by asking the patient to stand first on one foot and then on the other, first with the eyes open and then with the eyes closed; and to walk along a line, placing one heel in front of the other toe.

A complete general physical examination should be made. Examination of the peripheral blood-vessels, the blood-pressure, the ears, and the urine is often of great importance.

Accessory methods of investigation which may be necessary include examination of the cerebro-spinal fluid and radiography of the skull and spine.

14 ELECTRO-ENCEPHALOGRAPHY

The observation of Berger (1929) that it was possible to record changes of electrical potential occurring in the human brain has already led to important advances in knowledge. The changes of electrical potential recorded are usually of the order of from 5 to 50 millivolts, and have a duration of from 1 second down to 20 milliseconds. The recording of such small electrical changes has been rendered possible by the development of thermionic amplification. For ordinary purposes electrodes are applied to the unshaved scalp. Technical details of the process are reviewed by Walter (1938).

The first electrical rhythm, described by Berger as the alpha rhythm, and later referred to by Adrian and others as the Berger rhythm, consists of an almost sinusoidal discharge with a frequency of about 10 per second and with a potential varying irregularly from zero to about 100 microvolts in some subjects. The focus of the alpha discharge is usually limited to the parieto-occipital region of both hemispheres, but it is rarely seen elsewhere. It has been demonstrated by Berger and by Adrian that the alpha rhythm is inhibited

by visual activity and it is also decreased or abolished, when the eyes are shut, by intellectual concentration, such as that required for mental arithmetic, and also by a startling external stimulus, such as a noise or sensation. It is, therefore, suggested that the alpha rhythm is an indication of physiological rest in that area of the occipital cortex concerned with the integration of visual stimuli. Other rhythms have been described. So far as these have at present any clinical significance they are described in the sections on sleep (p. 827), intracranial tumour (p. 244), epilepsy (p. 864), and myoclonus (p. 887).

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CHAPTER II

THE CRANIAL NERVES

1. THE FIRST OR OLFACTORY NERVE

THE OLFACTORY FIBRES

THE olfactory portion of the nasal mucous membrane contains bipolar sensory cells which constitute the olfactory neurones of the first order. Their central processes, which are unmyelinated, form small bundles, the filaments of the olfactory nerve, which pass through the cribriform plate of the ethmoid bone and enter the olfactory bulb. From the olfactory bulb further fibres reach the brain through the olfactory tract. As this approaches the cerebral hemisphere it divides into a median and a lateral root on either side of the anterior perforated space. The lateral root is the more important in man and carries fibres to the olfactory area of the cerebral cortex, which includes the uncinate gyrus and part of the hippocampus. The anterior commissure unites the olfactory cortical regions of the two hemispheres and probably also carries fibres from each olfactory tract to the opposite hemisphere.

DISTURBANCES OF THE SENSE OF SMELL

By the sense of smell we perceive not only scents but also flavours, the sense of taste being concerned only with the recognition of the four primary tastes—sweet, bitter, salt, and acid. It is a commonplace observation that a cold in the head which abolishes the sense of smell abolishes also flavours but not the primary tastes.

In testing the sense of smell small bottles containing oil of peppermint, oil of cloves, tincture of asafoetida, and other scents are applied in turn to each nostril and the patient is asked if he recognizes them. It must be remembered that many normal individuals with an acute sense of smell find difficulty in naming scents.

Anosmia, or loss of the olfactory sense, is occasionally congenital and sometimes hereditary. It may occur either temporarily or permanently as a result of infections of the nose. The sense of smell is lost when the olfactory tract is interrupted. This may occur on one or both sides as a result of head injury either with or without fracture of the base of the skull in the anterior fossa. The olfactory tract may be compressed by tumours, especially by meningiomas growing from the olfactory groove, or less frequently by tumours of the frontal lobe or in the region of the optic chiasma, or by the distended cerebral hemispheres in obstructive hydrocephalus. It may be involved in meningitis, both purulent and syphilitic and, like the

optic nerves, degenerate in tabes. It is doubtful whether complete anosmia is produced by lesions of the olfactory cortex, probably because fibres from each olfactory tract reach both cerebral hemispheres. A lesion of one uncinate gyrus, however, may cause a reduction in olfactory acuity in the nostril of the same side. Irritative lesions in the neighbourhood of the uncinate gyrus are liable to cause olfactory hallucinations, which are usually associated with disturbance of consciousness and involuntary convulsive movements of the lips, jaw, tongue, and pharynx—uncinate fits (see p. 248).

The treatment of anosmia is that of the causative lesion, but loss of the olfactory sense, due to lesions of the tract, is almost always permanent.

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2. THE SECOND OR OPTIC NERVE

The course of the optic nerve and the situation of the retinal fibres within it, together with methods of investigating the visual fields, are described on pp. 52–4.

The Visual Acuity.

Distant vision may be estimated by testing the patient's power of reading Snellen's type at a distance of 6 metres. The visual acuity is expressed as a fraction, the distance of the eye from the type, i.e. 6 metres, being divided by the distance at which the patient should be capable of reading the smallest type he can read. Normal visual acuity is thus 6/6ths. If at 6 metres the patient can only read type which he should be capable of reading at 60 metres, the visual acuity is said to be 6/60ths. Near vision is tested by Jaeger's types. For more accurate investigation of the visual acuity perimetry is necessary.

The Visual Fields.

Methods of investigating the visual fields are described on p. 52.

OPHTHALMOSCOPY

Examination of the fundus oculi is of such importance in the investigation of cases of nervous disease that it should form part of the routine examination of every patient. Direct ophthalmoscopy

has been simplified by the introduction of the electric ophthalmoscope Except when the pupil is greatly contracted, it is usually possible to examine the optic disk; but to make a complete examination of the macular region and of the periphery of the retina, the pupil should previously be dilated with homatropine. The normal optic disk is circular and rosy pink in colour, though slightly paler than the surrounding retina It possesses a well-defined edge and a depression— the physiological cup—from which the arteries and veins emerge. The normal appearance of the disk and its vessels can only be learned from experience. The following are the most important abnormalities. The disk may be pinker than normal, from hyperaemia, or abnormally pale from optic atrophy. Its edge may be indistinct. The physiological cup may be filled or the disk may be actually swollen above the level of the surrounding retina, the swelling being measured in dioptres. The veins of the disk may be congested, the arteries may be thickened and tortuous, or both arteries and veins may be abnormally fine and narrow. Pulsation of the arteries is abnormal, but pulsation of the veins is sometimes seen in normal individuals. Finally, the disk and surrounding area of the retina may be the site of exudate and haemorrhages.

The macular region is situated about two disk-breadths horizontally outwards from the outer edge of the disk. It is somewhat darker than the rest of the fundus and is almost devoid of bloodvessels The principal abnormalities to be found in the macula are an extension of oedema from the optic disk—the macular fan—and a stippled, star-shaped, or haemorrhagic exudate in cases of retinal arterio-sclerosis and hypertensive retinitis. A cherry-red spot is seen at the macula in cases of obstruction of the central artery of the retina and in the infantile form of cerebro-macular degeneration, while pigmentation is seen in the late infantile and juvenile forms of this disease Since the macula is the most sensitive part of the retina and is concerned in central vision, macular lesions cause great impairment of visual acuity.

Finally the whole of the periphery of the retina should be inspected. The condition of the arteries and the veins should be noted Retinal arteriosclerosis first manifests itself in displacement of the veins at the point where they are crossed by the arteries, with congestion of the portion distal to the crossing. Greater degrees of arterial thickening lead to tortuosity and irregularity of the arteries, with an increased light refraction from their surface—silver wire arteries. In retinal arteriosclerosis and hypertensive retinitis haemorrhages and exudate may be seen in the peripheral parts of the retina. Black pigmentation is characteristic of the various forms of choroidoretinitis A retinal angioblastoma may sometimes be seen in cases of

Lindau's disease and a phakoma in tuberous sclerosis, and in cases of general miliary tuberculosis and tuberculous meningitis tubercles may be seen in the retina as roundish, yellow bodies about half the size of the disk.

LESIONS OF THE OPTIC NERVE

Papilloedema (Choked Disk)

By papilloedema is meant simply an oedema of the optic papilla or disk, without reference to its underlying cause. Like oedema in other parts of the body, papilloedema may be due to different pathological states, of which the following are the most important:

1. Increased intracranial pressure.
2. Inflammatory conditions of the optic nerve, optic neuritis and *retrobulbar neuritis*
3. Oedema associated with disease of the retinal arteries and retinal exudation, as in chronic nephritis and malignant hypertension.
4. Venous obstruction, due to neoplasms and gumma of the orbit, thrombosis of the central vein of the retina, some cases of cavernous sinus thrombosis, traumatic arteriovenous aneurysm of the internal carotid artery and the cavernous sinus, intra-thoracic venous obstruction, as by neoplasms, aneurysm of the aorta, and severe emphysema.
5. Changes in the composition of the blood, as in severe anaemia and erythraemia

For the study of nervous diseases the papilloedema due to increased intracranial pressure and that associated with optic and retrobulbar neuritis are the forms of greatest importance.

Papilloedema due to Increased Intracranial Pressure.

The optic nerve, which developmentally and histologically is part of the brain, is surrounded like the brain by the three meninges Immediately covering the nerve is the pia mater and superficially to that the arachnoid, both of which are prolonged forwards to fuse with the sclerotic. Outside both is the dura mater, which is continuous anteriorly with the periosteum of the orbit. The optic nerve, therefore, is surrounded by a subarachnoid space which is continuous with the cerebral subarachnoid space. A rise in the pressure of the cerebro-spinal fluid in the cerebral subarachnoid space is freely conducted to the optic subarachnoid space, where it has a double effect, causing compression of the central vein of the retina where it crosses the space, and impeding lymphatic drainage from the retina and optic nerve (Paton and Holmes).

The result of this combined venous and lymphatic obstruction is congestion and oedema of the optic disk and retina. The following

are the principal causes of increased intracranial pressure leading to papilloedema:

1. *Intracranial Tumour.* Not all intracranial tumours cause papilloedema The presence or absence of this symptom and its severity when present may, therefore, be an aid to the localization of a tumour. Generally speaking, the occurrence of papilloedema depends upon whether the tumour is so placed as to cause a rise in the tension of the cerebro-spinal fluid and also upon its rate of growth. It is almost constantly present in the case of tumours occupying the temporosphenoidal lobe, the cerebellum, and the fourth ventricle, but is absent in about half the cases of subcortical and pontine tumours. It is frequently late in developing when the tumour is in the pre-·frontal region or arises near the vertex. Cerebellar tumours give rise to papilloedema of the greatest severity. The more rapidly a tumour grows the more likely is it to cause papilloedema. I have known papilloedema absent in patients with a very large but slowly growing angioblastomatous cyst of the cerebellum. Inequality of the degree of oedema in the two eyes is not uncommon, but if the difference is not great it is of no localizing value. A tumour arising near one optic foramen tends to prevent the development of papilloedema in that eye by cutting off the optic sheath from communication with the cerebral subarachnoid space. In such cases primary optic atrophy may develop on the side of the tumour and may be associated with papilloedema on the opposite side (Syndrome of Gowers, Paton, and Foster Kennedy)

2 *Cerebral Abscess.* Papilloedema is inconstant in cerebral abscess and may be late in developing.

3. *Hydrocephalus.* Hydrocephalus from any cause may lead to papilloedema, but in some cases the pressure of the distended floor of the third ventricle upon the optic ̍chiasma and nerves causes primary optic atrophy, with which some degree of papilloedema may be associated.

4. *Meningitis.* Meningitis causes papilloedema less frequently than might be expected in view of the rise in pressure of the cerebro-spinal fluid, which occurs in this condition, possibly because meningeal adhesions tend to wall off the optic sheaths. Papilloedema is often absent in tuberculous meningitis and is most frequent in meningitis of long duration, such as may occur in meningococcal infection. In all forms of meningitis the infecting organism may penetrate the optic nerve, causing true optic neuritis.

5. *Intracranial Sinus Thrombosis.* This leads to an increase in the pressure of the cerebro-spinal fluid by diminishing its paths of absorption into the intracranial venous system.

6. *Subarachnoid Haemorrhage.* Haemorrhage into the subarach-

noid space may cause papilloedema owing to blood being driven into, and distending, the subarachnoid space of the optic sheaths. The commonest cause of this condition is leakage from an intracranial aneurysm.

Ophthalmoscopic Appearances of Papilloedema.

In the earliest stage of papilloedema the retinal veins appear congested and the optic disk is pinker than normal. The disk edge appears blurred at its upper and lower margins, and this blurring extends to the nasal side before the temporal. An increase in the oedema causes filling of the physiological cup, and later the nerve-head becomes elevated above the general retinal level, sometimes by as much as 8 or even 10 dioptres. In severe cases oedema spreads into the retina causing a macular 'fan'. Distension of the retinal veins is extreme, and haemorrhages may be found on the retina and on the disk itself. If the intracranial pressure does not subside the condition progresses to optic atrophy. The swelling of the disk diminishes, and it becomes paler. The arteries become constricted and the perivascular lymph-spaces thickened. Finally, in a typical case, the disk is pale and flat, the physiological cup remaining filled, and the edges of the disk being less distinct than formerly. The arteries are constricted, but the veins often remain congested for a considerable time.

The Visual Fields in Papilloedema.

In the earlier stages of papilloedema the only change in the visual fields may be enlargement of the blind spots. Later concentric constriction of the fields sets in with a diminution in the visual acuity of the remainder, terminating ultimately in blindness. It should be noted that papilloedema may be associated with other changes in the visual fields due to lesions involving other parts of the visual fibres.

OPTIC NEURITIS AND RETROBULBAR NEURITIS

The term 'optic neuritis' used to be employed for all conditions associated with oedema of the optic disk, so that 'optic neuritis' was described as a symptom of intracranial tumour. Since neuritis implies inflammation this was a misnomer, and the name is now confined to infective or toxi-infective conditions of the optic nerve. The distinction between optic neuritis and retrobulbar neuritis is based upon an ophthalmoscopic rather than a pathological difference and is apt to be misleading. If a neuritis of the optic nerve is sufficiently anterior to cause oedema of the disk it is described as optic neuritis or papillitis; if it is more posteriorly situated so that the direct effects of the inflammation are not visible ophthalmo-

scopically it is called retrobulbar neuritis. This accident of localization is in many cases of no pathological import.

Causes of Optic and Retrobulbar Neuritis.

The causes of optic and retrobulbar neuritis are few.

1. *Disseminated Sclerosis* must be placed first in frequency, and most cases are undoubtedly due to this disease. The optic nerve lesion, which is usually unilateral, may be the first symptom and precede other manifestations by many years. In other cases other signs may have preceded it and may be found on routine examination of the nervous system, for example, nystagmus, intention tremor, diminution or absence of the abdominal reflexes, and extensor plantar responses. Examination of the cerebro-spinal fluid may show abnormalities suggestive of disseminated sclerosis, especially an abnormal colloidal gold curve. The changes in the optic nerve are the same as those of disseminated sclerosis elsewhere in the nervous system, namely demyelination of the nerve-fibres, with inflammatory exudation and, later, gliosis. Vision is hardly ever permanently lost as a result of this disease.

2. *Disseminated Myelitis with Optic Neuritis*. This is a rare disease, closely allied to disseminated sclerosis, both clinically and pathologically. Bilateral optic or retrobulbar neuritis is associated with transverse myelitis. Acute bilateral retrobulbar neuritis occurring without other lesions of the nervous system is probably a closely related disorder. It sometimes occurs also in diffuse sclerosis.

3. *Syphilis* A syphilitic lesion of the optic nerve, with the characteristic endarteritis, is a rare cause of retrobulbar neuritis. Diagnosis with the aid of serological tests is usually easy.

4 *Zoster* Optic neuritis, going on to atrophy, with complete loss of vision, has been described in herpes zoster affecting the cornea.

5 *Orbital Infections*. The optic nerve may be involved in inflammation spreading directly from the orbit, where it may be secondary to infection of the nasal air sinuses or dental abscess.

6. *Meningitis and Encephalitis*. As we have seen, infection may spread into the nerve from the meninges in any form of meningitis, and optic neuritis sometimes occurs in acute disseminated encephalomyelitis

7 *Vitamin Deficiency*. Bilateral retrobulbar neuritis followed by optic atrophy has been attributed to vitamin B deficiency (Moore, 1937).

Clinical Features of Optic and Retrobulbar Neuritis.

Acute inflammation of the optic nerve leads to pain in and behind the eye on ocular movement and on pressure. If the inflammation

extends to the optic disk it causes papillitis, with the appearances of papilloedema, though the swelling of the disk is usually slight and haemorrhages are uncommon When the inflammation is confined to the retrobulbar portion of the nerve the disk appears normal until signs of atrophy appear. This occurs in most cases, and is indicated by pallor of the disk, involving, in mild cases the temporal fibres, in severe cases the whole disk. Even after papillitis the physiological cup is usually preserved and the disk edge and vessels appear normal.

In inflammation of the optic nerve the macular fibres suffer most, either because the central part of the nerve is most involved or because, being the most highly evolved part of the visual afferent system, they are the most susceptible to damage. In consequence the characteristic visual field defect is a central scotoma, the loss for red and green objects being greater than that for white. In most cases improvement occurs in a few weeks, but the functional manifestation of the residual atrophy is often a central scotoma, much smaller than that of the acute stage Helpful points of distinction between optic neuritis with papillitis, and papilloedema due to increased intracranial pressure are that in the former the swelling of the disk is slight in comparison with the loss of vision, in the latter the reverse is usually the case, and in optic neuritis the usual field defect is a central scotoma, in papilloedema a peripheral concentric constriction.

Optic Atrophy

'Primary' and 'Secondary' Optic Atrophy.

As the foregoing sections of this chapter show, optic atrophy may follow a variety of pathological states, and other causes have yet to be mentioned. When the pathological causes of optic atrophy were less understood a confusing distinction was drawn between 'primary' and 'secondary' optic atrophy. This is purely an ophthalmoscopic distinction, 'secondary' optic atrophy being the term used when atrophy follows some observable change in the retina and optic disk, and 'primary' atrophy when no such cause is ophthalmoscopically obvious. We now recognize that even the 'primary' atrophies are secondary to some pathological state such as pressure upon or poisoning of the optic nerve.

Causes of Optic Atrophy.

(1) Familial Disorders.

In these obscure diseases the optic atrophy is probably due to a primary degeneration which affects various parts of the nervous system including the retinae and optic nerves.

(i) *Cerebro-macular Degeneration.* The infantile form, amaurotic family idiocy, Tay-Sachs disease (see p. 556), is characterized by a lipoid degeneration of the ganglion cells of the retina, atrophy of which at the macula is responsible for the cherry-red spot.

In the late infantile and juvenile forms (Batten-Mayou type) the cherry-red spot is absent, but the macula may be pigmented. Macular degeneration may occur also at puberty or early in adult life as an inherited disorder (Behr).

(ii) *The Hereditary Ataxias* (see p. 567). In this group of closely related disorders there is degeneration of various parts of the nervous system, especially of the cerebellum and its tracts. Any form of hereditary ataxia may be associated with optic atrophy.

(iii) *Retinitis Pigmentosa.* This is an hereditary disease which is inherited in some sibships as a Mendelian dominant, less often as a recessive. It is often associated with nerve deafness and with a family history of epilepsy. There is a characteristic spidery black pigmentation of the periphery of the retina, and the optic disk exhibits a yellowish waxy pallor and much reduction in the calibre of the vessels. The victims of this disease suffer from night-blindness and progressive concentric constriction of the visual fields.

Retinitis pigmentosa is also a feature of the Laurence-Biedl-Moon syndrome (see p. 820).

(iv) *Leber's Hereditary Optic Atrophy.* This is a rare hereditary disease which is transmitted as a sex-linked recessive. There is a sudden onset of bilateral visual impairment, usually between the ages of 15 and 30. The fields of vision show central scotomas. Papillitis may be present in the acute stage: later the disks are atrophic. It has been attributed to swelling of the pituitary, but is more probably a familial form of optic or retrobulbar neuritis.

(v) *Congenital Optic Atrophy.* This may be hereditary (Thompson and Cashell) or an element in congenital diplegia.

(2) *Optic Atrophy following Retinal Lesions.*

In this group the cause of the optic atrophy is obvious on retinoscopy. It includes the various forms of retinitis and choroido-retinitis and vascular lesions of the retina.

(3) *Optic Atrophy following Papilloedema.*

Optic atrophy following papilloedema has been described in a previous section of this chapter (see p. 139).

(4) *Optic Atrophy following Acute Optic and Retrobulbar Neuritis.*

The causes of this are discussed on p. 140.

(5) Syphilitic Optic Atrophy.

The optic atrophy of tabes and general paralysis is primary, i.e. not preceded by visible retinal change. Both eyes are affected, but not always equally at first. There is much evidence that the primary change is an inflammation of the pial sheath of the optic nerves and that the myelin sheaths suffer before the axis-cylinders (Stargadt, Behr). Others believe, however, that there is some primary degeneration of the nerve-fibres.

Paton distinguishes two types: a parenchymatous degeneration with slow onset, losses in the peripheral fields and maintenance of good central visual acuity for a long period, and an interstitial lesion with fairly rapid loss of central vision and little involvement of the peripheral fields for white. The disk is grey or white, often with a bluish tint. The physiological cup is preserved; the stippling of the lamina cribrosa is visible. The disk edge and vessels are normal.

(6) Toxic Optic Atrophy.

The optic nerve fibres are susceptible to a number of poisons, though their mode and site of action are little understood. Among these are tobacco, lead, arsenic (especially tryparsamide) methyl mercury iodide, toxic substances associated with methyl alcohol, carbon bisulphide, quinine, and aspidium filix mas   It is uncertain whether tobacco, methyl alcohol, and carbon bisulphide cause degeneration of the retinal ganglion cells or act on the nerve-fibres. Quinine and aspidium filix mas are said to produce spasm of the retinal arteries and hence retinal atrophy. Any severe anaemia, *especially that following severe internal haemorrhage, may cause optic* atrophy, probably by causing the death of the ganglion cells. So too may diabetes

(7) Pressure.

Pressure is a common and important cause. In the eye itself it is produced by glaucoma. It may occur in the optic foramen, if this is narrowed by bony overgrowth, as in Paget's osteitis, or if a tumour arises from the optic nerve or its sheath, or even as the result of a thickened ophthalmic artery. Behind the foramen the commonest cause of pressure is a tumour, either of the pituitary body, or of the cranio-pharyngeal pouch, or a meningioma arising above the sella turcica or in the olfactory groove, or a glioma of the optic chiasm, of the frontal lobe or of the tip of the temporal lobe. Pressure may also arise from localized arachnoiditis of the optic chiasma, the distended floor of the third ventricle in obstructive hydrocephalus,

from an intracranial aneurysm, or from arterio-sclerotic internal
carotid arteries In the diagnosis of pressure upon the optic nerve
the radiography of the optic foramina is often of value.

Visual Fields in Optic Atrophy.

No generalization can be made about the visual fields in optic
atrophy, since they depend entirely upon the cause. After papill-
oedema there are usually enlargement of the blind spot and peripheral
concentric constriction. Retrobulbar neuritis and the toxic ambly-
opias are usually associated with central scotomas, but in poisoning
with quinine and aspidium filix mas the peripheral part of the
fields suffers more than the central. In tobacco amblyopia the sco-
toma is centro-caecal. Pressure lesions may produce central scotoma
or other partial field defects. It must be remembered too that optic
atrophy following both papilloedema and pressure upon the optic
nerve may indirectly be due to an intracranial lesion which involves
the visual fibres more posteriorly also, and itself causes visual field
defects.

Prognosis of Optic Nerve Lesions.

The prognosis of lesions of the optic nerve depends chiefly upon the
extent to which the cause can be removed. When papilloedema is
due to increased intracranial pressure, relief of this is usually followed
by marked improvement in vision, provided optic atrophy has not
already developed. Similarly great improvement in vision often
follows quite rapidly the removal of direct pressure upon the optic
nerve. A considerable degree of recovery can usually be anticipated
in optic neuritis and retrobulbar neuritis due to disseminated sclerosis,
and also in sporadic cases of acute bilateral optic and retrobulbar
neuritis, though occasionally vision is permanently lost in this con-
dition. The outlook is less satisfactory in optic atrophy of toxic
origin, though some improvement may occur if exposure to the toxin
can be terminated and recovery from tobacco amblyopia is usually
satisfactory. Tabetic optic atrophy, when severe enough to cause
visual impairment, progresses in spite of all treatment.

Treatment of Optic Nerve Lesions.

The treatment of lesions of the optic nerve is primarily that of the
causal disorder. Patients suffering from retrobulbar neuritis should
be forbidden to read and should rest their eyes as much as possible.
When retrobulbar neuritis is attended by much pain this may be
relieved by the application of leeches to the temple. Potassium
iodide may promote the absorption of inflammatory exudate.

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3 THE THIRD, FOURTH, AND SIXTH NERVES

Third-Nerve Paralysis

After leaving the nucleus the fibres of the third nerve sweep outwards and forwards through the posterior longitudinal bundle, the red nucleus, and the medial margin of the substantia nigra to emerge from the brain-stem along the bottom of the sulcus oculomotorius on the medial aspect of the basis pedunculi (Fig. 3). The nerve passes forwards between the posterior cerebral and superior cerebellar arteries, close to the posterior communicating artery, and pierces the dura mater beside the posterior clinoid process in a small triangular space between the free and attached borders of the tentorium cerebelli. It then passes through the lateral wall of the cavernous sinus, where it lies close to the fourth, sixth, and first division of the fifth, nerves, and enters the orbit through the superior orbital fissure between the two heads of the external rectus muscle. Here it divides into two branches, the upper supplying the levator palpebrae and the superior rectus, and the lower the internal and inferior recti and the inferior oblique, the nerve to which supplies the short root to the ciliary ganglion.

Paralysis of the third nerve causes ptosis, complete internal ophthalmoplegia, and paralysis of the superior, internal, and inferior recti, and inferior oblique. The pupil is widely dilated owing to paralysis of the sphincter pupillae and the unantagonized action

Fig. 13. Recovering third nerve palsy on right side in a case of ophthalmoplegic migraine. (Note the ptosis, dilated pupil, and abduction of the eye due to unopposed action of the external rectus, and the over-action of the frontalis muscle.)

of the dilator, and fails to react. Accommodation is paralysed. The unantagonized external rectus causes outward deviation of the eye, and the only possible ocular movements are abduction, carried out by the external rectus, and a movement of depression, internal rotation, and abduction by the superior oblique. Paralysis of the levator palpebrae superioris causes ptosis of the upper lid, and the resulting closure of the eye masks the diplopia which becomes evident to the patient when the lid is passively raised (Fig. 13).

Although lesions of the third nerve usually cause both external and internal ophthalmoplegia, it may happen that in a partial lesion the irido-constrictor fibres escape, or that in recovery from a complete lesion the intrinsic fibres may recover before the extrinsic. When both the third nerve and the ocular sympathetic are injured, as may happen with a lesion just behind the orbit, the pupil is not dilated.

FOURTH-NERVE PARALYSIS

The fibres of the fourth nerve after leaving the nucleus turn backwards through the periaqueductal grey matter on the medial aspect of the mesencephalic root of the trigeminal nerve, and then downwards and medially to decussate in the superior medullary velum, whence the nerve emerges just behind the corpora quadrigemina. It then passes round the cerebral peduncle, lying between the peduncle and the temporal lobe, and pierces the free border of the tentorium cerebelli lateral to the third nerve to enter the lateral wall of the cavernous sinus. It enters the orbit through the superior orbital fissure above the ocular muscles and terminates in the superior oblique. A lesion of the fourth nerve causes paralysis of this muscle with weakness of movement of the eye downwards and outwards. For the character of the resulting diplopia see p. 67. When the lesion involves the nucleus or the fibres of the nerve within the midbrain before their decussation in the superior medullary velum, the paralysis of the superior oblique is on the opposite side to the lesion. When the nerve is damaged in its extracerebral course the paralysis is ipsilateral.

SIXTH-NERVE PARALYSIS

The fibres of the sixth nerve after leaving the nucleus just below the floor of the fourth ventricle pass forwards through the pons to emerge at its inferior border above the lateral side of the pyramid of the medulla. It has a long extracerebral course along the base of the brain before it pierces the dura mater of the posterior fossa, just below the dorsum sellae. Like the third and fourth nerves, it lies in the lateral wall of the cavernous sinus, whence it passes through the superior orbital fissure to terminate in the external rectus muscle. A lesion of the sixth nerve causes paralysis of this muscle with loss of abduction of the eye, which is deviated inwards by the unantagonized internal rectus (Fig. 14). For the character of the resulting diplopia, see p. 67.

CAUSES OF PARALYSIS OF THE THIRD, FOURTH, AND SIXTH NERVES

The third, fourth, and sixth nerves may be damaged singly or together and on one or both sides.

Within the brain-stem their nuclei or intracerebral fibres may be damaged by neoplasms, vascular lesions, encephalitis, or disseminated sclerosis, and in the case of the sixth nerve syringobulbia. Congenital aplasia of the nuclei may cause bilateral external rectus paralysis with or without facial paralysis.

Intracranial tumour may cause direct compression of the nerves at any point in their course, but, in addition,

FIG. 14. Congenital bilateral external rectus palsies.

Increased intracranial pressure due to intracranial tumour or abscess remote from the nerves, or to hydrocephalus, may indirectly impair their conductivity. The sixth nerve most often suffers in this way, and sixth-nerve paralysis may occur with a tumour in any situation. Supratentorial tumours probably cause this by displacing the brain-stem downwards and so stretching the nerve. The third nerve may also suffer, especially with tumours of the temporosphenoidal lobe. The fourth nerve escapes.

Neoplastic infiltration of the meninges may compress the nerves in their passage across the base of the skull and through the dura mater. Such meningeal metastases may be derived from a primary glioma in the brain or from a primary extracerebral growth, often arising in the nasopharynx, with secondaries in the bones of the base of the skull.

Intracranial aneurysm, especially when arising near the circle of

Willis, may directly compress one or more of the oculomotor nerves, especially the third nerve, or they may be subjected to pressure from extravasated blood or clot after rupture of the aneurysmal sac.

Ophthalmoplegic migraine is the term applied to cases of recurrent ocular palsy, the onset of which is associated with severe headache and which tend to recover in the course of days or weeks, only to relapse subsequently, finally becoming permanent. The third, fourth, or sixth nerve may be involved (Fig. 13). The relationship of this condition to true migraine is doubtful (see p. 848).

Syphilis is a common cause of ocular palsies through implication of the nerves in syphilitic meningitis and is the commonest cause of a painless third-nerve palsy.

In *meningitis*, either pyogenic or tuberculous, both infection and compression of the nerves may occur. Extension of infection from the middle ear to the meninges overlying the tip of the petrous process of the temporal bone is responsible for sixth-nerve paralysis, with or without trigeminal neuritis, occasionally associated with mastoiditis—Gradenigo's syndrome. The basal meninges and cranial nerves may be more extensively involved in a spread of infection from osteitis of the bones of the base of the skull.

In *encephalitis lethargica* and *disseminated sclerosis* the inflammatory process may occasionally involve the oculomotor nerves and the sixth nerve may suffer in poliomyelitis, which may be the cause of some cases of external rectus palsy of sudden but unexplained onset in children.

Polyneuritis. The cranial nerves, including those supplying the ocular muscles, may be the site of toxic polyneuritis, either with or without polyneuritis involving the limbs, *polyneuritis cranialis.* The sixth nerve is occasionally paralysed in diphtheria.

'*Rheumatic*' *neuritis* is the term applied to certain ocular palsies of unexplained pathology which seem akin to 'Bell's palsy' of the facial muscles. The paralysis, which usually involves the external rectus, may follow exposure to a draught and usually recovers completely.

Vascular lesions of the oculomotor nerves are not uncommon in elderly patients, especially those with high blood-pressure. Either the third, fourth, or sixth may be involved. The lesion may be either haemorrhage or thrombosis, and complete recovery of function in two or three months is the rule.

Diabetic ocular palsies are probably of the same nature.

Within the *cavernous sinus* the oculomotor nerves may be paralysed as a result of thrombo-phlebitis of the sinus, or of the pressure of an aneurysm of the internal carotid artery

Paralysis of one of the oculomotor nerves, usually the sixth,

occasionally follows the administration of a *spinal anaesthetic.* Its precise cause is unknown. Recovery occurs in a few weeks.

Within the sphenoidal fissure the nerves may be implicated in *orbital periostitis.* This may be due to an extension of infection from the nasal sinuses or, rarely, to syphilis. I have seen several cases in which it has followed the extraction of a tooth from the upper jaw, but in most cases no cause can be found and the condition is ascribed to an 'idiopathic' or 'rheumatic' infection. The onset is rapid. In most cases, in addition to the third, fourth, and sixth nerves, the first division of the fifth nerve is involved, with pain associated with hyperalgesia and analgesia over its cutaneous distribution. Pain in and behind the eye is often severe and the eye, which is tender on pressure, is usually slightly proptosed. In some cases some of the contents of the sphenoidal fissure escape, and the ocular palsy may be limited to the third or to the sixth nerve. The prognosis in periostitis of the sphenoidal fissure is good, and in the idiopathic variety complete recovery is likely to occur in a few months. A somewhat similar clinical picture is produced by the invasion of the orbit by *carcinoma arising in a nasal sinus.* The onset, however, is more gradual and steadily progressive, and proptosis is usually more marked than in orbital periostitis.

Treatment of Lesions of the Oculomotor Nerves.

Treatment is primarily that of the causal condition. When diplopia is present the patient should wear a shade or a frosted glass in front of one eye for the relief of discomfort and vertigo. It is sometimes possible to diminish diplopia by the use of a prism. During the acute stage of periostitis of the sphenoidal fissure leeches may be applied to the temple for the relief of pain, and aspirin and iodide should be given.

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4. THE FIFTH OR TRIGEMINAL NERVE

PERIPHERAL DISTRIBUTION

The fifth nerve contains both motor and sensory fibres. It is the principal sensory cranial nerve and represents a fusion of the sensory nerves of a number of metameric segments. It arises from the

inferior surface of the pons on its lateral aspect by two roots, a large
sensory root and a small motor root. The two roots pass forwards
in the posterior fossa and, piercing the dura mater beneath the
attachment of the tentorium to the tip of the petrous part of the
temporal bone, enter a cavity in the dura mater overlying the apex
of the petrous bone. Here the sensory root expands to form the
semilunar or Gasserian ganglion, which contains the ganglion cells
of the sensory fibres and is homologous with the posterior root

Fig. 15 The Sensory Nerve Supply
of the Head.

Shaded.   1 Ramus Ophthalmicus.
Trigeminus 2.   ,, maxillaris.
           3.   ,, mandibularis.

White Vagus V = Nervus auricularis
              vagi.

Black   O. N. occipitalis major.
Cervical O′ N.   ,, minor
nerves   A N. auricularis magnus.

(Bing's Compendium of Regional Diagnosis,
3rd Edition)
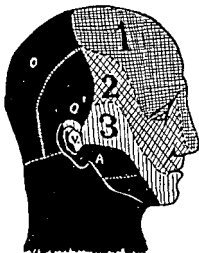
ganglia of the spinal nerves. The ganglion gives rise to three large
nerve-trunks, which constitute the three divisions of the trigeminal
nerve, namely, the ophthalmic or first division, the maxillary or
second, and the mandibular or third (Fig. 15) The motor root of
the nerve passes forwards beneath the ganglion and becomes fused
with the third division

The Ophthalmic Nerve.

The ophthalmic division after lying in the lateral wall of the
cavernous sinus together with the third, fourth, and sixth nerves,
enters the orbit through the superior orbital fissure. It supplies the
skin of the face and scalp, as follows: a narrow zone adjacent to the
middle line throughout the length of the nose; the upper eyelid
and the scalp from the base of the nose and the eyelid as far back
as the lambdoidal suture in the midline and for about 3 inches
laterally to this. The first division also supplies sensory fibres to the
eye, including the conjunctiva and the cornea, to the iris, and to
the mucous membrane of the frontal sinuses and the upper part of
the nose. It is uncertain whether secretory fibres to the lachrymal

gland are derived from the fifth nerve or from the geniculate ganglion of the facial nerve, reaching the gland by the great superficial petrosal, the sphenopalatine ganglion, the second division of the trigeminal and the anastomosis between the temporomalar and the lachrymal nerves.

The Maxillary Nerve.

The maxillary nerve after leaving the Gasserian ganglion passes through the foramen rotundum into the sphenopalatine fossa. It enters the orbit as the infra-orbital nerve through the inferior orbital fissure, and then passing through the infra-orbital canal reaches the face through the infra-orbital foramen. It supplies the skin of the upper lip as far as the middle line and the skin of the cheek between the area on the nose supplied by the ophthalmic nerve and a line passing upwards and slightly outwards from the angle of the mouth, crossing the zygoma about midway between the outer canthus of the eye and the ear, and continuing upwards to join the lateral boundary of the area of supply of the first division on the scalp, about the middle of the temporal ridge. The maxillary division also supplies the mucous membrane of the maxillary antrum and the lower part of the nose, together with the mucous membrane of the upper lip, the hard palate, and the soft palate, except its posterior border, together with the teeth of the upper jaw.

The Mandibular Nerve.

The mandibular nerve is formed by a fusion of the third division of the Gasserian ganglion with the motor-root. These two roots pass out of the skull by the foramen ovale and unite to form a single trunk in the infra-temporal fossa. The mandibular nerve supplies the skin of the lower lip and chin, together with a zone of the cheek about an inch wide laterally to the lateral boundary of the cutaneous supply of the maxillary nerve and bounded below by the border of the area supplied by the cervical plexus. Above this its distribution expands to include the tympanic membrane, the external auditory meatus, the upper half of the lateral aspect of the auricle and the skin of the temple, where its distribution is bounded anteriorly by the lateral border of the second division, above by the lateral border of the first division, and behind by a line drawn upwards from the external auditory meatus to the vertex in the region of the lambdoidal suture. In addition to this cutaneous area the mandibular nerve supplies the mucous membrane of the cheek, lower jaw, floor of the mouth, and anterior two-thirds of the tongue, and the teeth of the lower jaw. From the chorda tympani taste fibres pass to the anterior two-thirds of the tongue by the lingual nerve, which is a branch of the

mandibular nerve. Meningeal branches from the trigeminal nerve supply the dura mater of the greater part of the skull above the tentorium and of the tentorium itself.

The cervical plexus supplies a zone of the cheek about one inch wide overlying the angle of the jaw

The Motor Root.

The motor root of the trigeminal nerve innervates the following muscles: the temporal, the masseter, the internal and external pterygoids, the anterior belly of the digastric and the mylohyoid muscle, the tensor tympani and the tensor palati.

CENTRAL CONNEXIONS

The motor nucleus of the trigeminal nerve lies in the lateral part of the tegmental portion of the pons The mesencephalic root is probably also motor. Incoming sensory fibres of the trigeminal divide, some passing into the principal sensory nucleus, which is situated in the substantia gelatinosa in the lateral part of the tegmentum of the pons, while others turn downwards to form the spinal tract which descends on the lateral side of the substantia gelatinosa. As the spinal tract passes downwards its fibres gradually terminate in the substantia gelatinosa which constitutes its terminal nucleus, the nucleus of the spinal tract. Both the spinal tract and its nucleus end in the upper part of the spinal cord about the level of the second spinal nerve. The sensory fibres entering the principal sensory nucleus are concerned with tactile and postural sensibility. From this nucleus relay fibres cross the middle line and form the trigemino-thalamic tract or trigeminal fillet at the inner end of the mesial fillet. The descending fibres of the spinal tract are concerned with the appreciation of pain and thermal sensibility Fibres from the ophthalmic division end in the lowest part of the spinal nucleus, fibres from the mandibular division in the highest part and those from the maxillary division intermediately Relay fibres from this nucleus cross the middle line and pass upwards in close relationship with the median fillet to join the spino-thalamic tract in the pons.

LESIONS OF THE TRIGEMINAL NERVE

Peripheral Lesions.

The nerve may be involved between the pons and the Gasserian ganglion in inflammatory lesions such as syphilitic meningitis, or it may be compressed by a tumour or an aneurysm. This part of the nerve commonly undergoes degeneration in tabes. In the Gasserian ganglion it may be compressed by a tumour of the ganglion itself or

of the pituitary body, or by a meningioma arising in its neighbourhood, or damaged by fracture of the base of the skull involving the middle fossa. With the sixth nerve it may be involved in inflammation spreading from the petrous bone in mastoiditis—Gradenigo's syndrome Inflammation of the ganglion occurs in trigeminal herpes zoster The peripheral branches of the nerve distal to the ganglion are a common site of interstitial neuritis and may be injured as a result of fracture of the bones of the face. Lesions of the nerve often cause pain, which is referred to the cutaneous area of its distribution and may be associated with cutaneous anaesthesia and analgesia. When the nerve is involved between the pons and the ganglion, all three divisions are likely to be affected, but lesions involving the ganglion itself may lead to symptoms which are confined to one division, most frequently the first. Lesions of the motor root cause weakness and wasting of the muscles of mastication on the affected side Wasting of the temporal muscle and of the masseter leads to hollowing above and below the zygoma, and when the patient is made to clench his teeth palpation reveals that contraction of these *muscles is less vigorous than on the normal side. When the mouth is opened the jaw deviates to the paralysed side as a result of the unantagonized action of the external pterygoid on the opposite side.*

Central Lesions.

The central connexions of the trigeminal nerve may be involved in lesions, especially tumours, syringobulbia and vascular lesions, affecting the pons, medulla, and uppermost cervical segments of the spinal cord The motor nucleus may be affected by a lesion in the lateral part of the tegmentum of the pons, in which case weakness of the muscles of mastication is usually associated with paresis of the external rectus and facial paresis on the affected side. Owing to the divergence of the sensory fibres of the trigeminal nerve within the brain-stem, dissociation of sensibility over the face commonly results from central lesions. A lesion of the pons which involves the principal sensory nucleus will cause anaesthesia to light touch over the trigeminal distribution, with preservation of appreciation of pain, heat, and cold On the other hand, lesions involving the medulla and the upper cervical segments of the spinal cord, by injuring the spinal tract and its nucleus, will cause analgesia and thermo-anaesthesia, with preservation of sensibility to light touch and sometimes severe and persistent spontaneous pain referred to the trigeminal area. This latter dissociation is characteristic of syringobulbia and of thrombosis of the posterior inferior cerebellar artery. Since the first division of the nerve is represented lowest and the third division highest in the spinal nucleus a lesion of the lowest part

of the medulla will cause analgesia limited to the first and second divisions only. Syringobulbia, however, leads to a characteristic progressive advance of the border of the analgesia, which begins posteriorly and gradually converges upon the tip of the nose and the upper lip, these being usually the last places to lose painful sensibility.

A lesion of the pons may also cause analgesia and thermo-anaesthesia on the opposite side of the face through damage to the crossed bulbo-thalamic tract.

Neuropathic Keratitis.

Neuropathic keratitis is a degenerative lesion of the cornea which may follow a lesion of the fifth nerve in any part of its course, including the pons, provided corneal analgesia results. Neuropathic keratitis is most frequently seen as a sequel of alcoholic injection of the Gasserian ganglion for trigeminal neuralgia. It may also occur as a result of vascular lesions or of tumours involving the pons and medulla and of compression of the fifth nerve in its peripheral course by a tumour, or of extension of inflammation to it in syphilitic or pyogenic meningitis. In some cases it occurs in association with corneal analgesia for which no cause can be found. Why corneal analgesia should cause neuropathic keratitis is at present unknown. It has been variously suggested that the corneal lesion is the result of loss of hypothetical trophic impulses, or of vasomotor disturbances, or is due to the analgesia's rendering the cornea more liable to small traumas, or to desiccation of the surface of the cornea resulting from a diminished secretion of tears. At the onset of neuropathic keratitis the whole corneal surface becomes faintly stippled and hazy and the cornea begins to lose its surface epithelium. Secondary infections may follow, resulting in more severe changes.

The treatment of neuropathic keratitis is described on p 164.

TRIGEMINAL NEURALGIA

Synonym: Tic douloureux.

Definition: A disorder characterized by paroxysmal brief attacks of severe pain within the distribution of one or more divisions of the trigeminal nerve usually without evidence of organic disease of the nerve.

Aetiology and Pathology.

The cause of trigeminal neuralgia is obscure. Histological examination of the Gasserian ganglion has revealed no changes which can be held responsible. The association of the disorder with dental infection and occasionally with infection of the maxillary antrum suggests that infection plays a part in aetiology, but the fact that

infection of the teeth and antrum is common, while trigeminal neuralgia is comparatively rare, appears to indicate that some additional factor exists which predisposes to the disorder. There is reason to believe that certain individuals are more liable than others to all forms of neuralgic pain, and it may be that in such persons chronic infection of the endings of the trigeminal nerve sets up attacks of pain which are perpetuated by functional changes within the central nervous system. Females are affected more frequently than males in the proportion of three to two. Heredity plays a part in causation in some cases. In 2 per cent. of Harris's cases one of the patient's parents had been a sufferer.

Rarely trigeminal neuralgia is a symptom of organic nervous disease. Unilateral or bilateral trigeminal neuralgia associated with spastic paraplegia is a distinctive syndrome, which in some cases has been proved to be due to disseminated sclerosis, and characteristic attacks rarely occur as a result of compression of the nerve by a tumour or in association with neurofibromatosis, facial hemiatrophy, facial myoclonus, or Paget's osteitis

Trigeminal neuralgia may begin at any age after puberty, but it is rare before middle life and in most cases the onset occurs at about the age of 50. Sometimes emotion, exposure to cold, or a blow on the face appears to precipitate the first attack.

Symptoms.

The characteristic feature of trigeminal neuralgia is the occurrence of brief, severe paroxysms of pain, which is usually for a long time confined to the distribution of one division of the nerve. The second and third divisions are the site of the pain with approximately equal frequency The first division is rarely affected and then usually only after the second division has been involved. Whether the pain first involves the second or third division, it usually in the course of time spreads to the other of the two lower divisions. In a small proportion of cases it is bilateral, though rarely from the onset.

In an attack the pain is usually most intense in, and may be confined to, part of the region supplied by the affected division. Thus it may be most marked in the cheek, the upper jaw, the lower jaw, or the tongue It tends to spread, however, through the rest of the divisional area. It is usually described as burning or stabbing. One of the most striking features of the attacks is that they tend to be precipitated by chill, by touching the face, as in washing, by talking, mastication, and swallowing. Many patients describe 'trigger zones', touching which will invariably excite an attack. The attacks are always brief and do not last longer than one or two minutes The pain is very severe and during the attack the patient may be in

agony. The pain often reflexly evokes spasm of the muscles of the face on the affected side, hence the term 'tic douloureux'. Flushing of the skin, lacrimation, and salivation may also occur.

In trigeminal neuralgia there is no reduction of sensibility over the distribution of the nerve So-called trophic changes in the skin have been described, but it is probable that these are the result of the patient's rubbing the face during the attack or of remedies which have been applied in his attempts to relieve the pain The attacks may interfere with the taking of food, and the recurrence of severe pain over a long period tends to cause loss of weight and depression. Fortunately the attacks usually cease at night, though they sometimes awaken the patient from sleep. Long periods of freedom from pain, lasting weeks or months, are the rule in the early stages.

Diagnosis.

There is usually little difficulty in diagnosis if attention is paid to the cardinal symptoms, especially the paroxysmal character of the attacks with freedom from pain in the intervals, the factors which precipitate them, and the absence of signs of an organic lesion of the nerve In rare cases, however, this syndrome may be associated with organic disease, for example, disseminated sclerosis or tumour of the eighth nerve Other signs of these disorders, however, are usually present. It is important to distinguish trigeminal neuralgia from the pain due to a gross lesion of the nerve, especially compression by a tumour. In such cases the pain is more persistent and is usually associated with impairment of sensibility in the distribution of the nerve, and weakness of the muscles supplied by the nerve is often present Trigeminal pain may follow lesions of the central connexions of the nerve within the brain-stem, for example, thrombosis of the posterior inferior cerebellar artery In such cases, however, other signs of a brain-stem lesion are present. Post-herpetic pain of trigeminal distribution is distinguished by the history of the zoster eruption, which leaves characteristic residual cutaneous scars, by the persistence of the pain, and by the impairment of sensibility. Tabes dorsalis is an occasional cause of paroxysmal attacks of pain within the trigeminal area The characteristic signs of tabes, however, render the diagnosis of the cause of the pain easy Neuritis of branches of the trigeminal nerve, especially of the supra-orbital and of the auriculo-temporal, causes pain within the distribution of the branch affected. In cases of neuritis there is a history of a recent acute onset ; the attacks of pain tend to last for hours, with paroxysmal exacerbations ; the affected nerve is tender on pressure ; and there is often hyperalgesia, or more rarely relative analgesia, over the cutaneous area supplied by the nerve.

Referred pain is extremely common within the trigeminal distribution, and possible causes of this must always be excluded. Frontal sinusitis and infection of the maxillary antrum tend to cause pain which is referred to the areas of the first and second divisions respectively. In such cases there may be oedema of the tissues overlying the infected air sinus and in addition to tenderness of the supra-orbital and infra-orbital nerves the bone also is tender. Radiography of the sinuses, transillumination, and examination of the nose may be necessary to establish the diagnosis. Diseases of the eye may cause severe referred pain, especially glaucoma, in which the pain is referred to the temple. Examination of the eye immediately reveals the cause of the trouble and a mistake in diagnosis is rare, though I have been asked to see a case of glaucoma which had been treated as trigeminal neuralgia. The teeth are a common source of referred pain. In addition to dental caries, which is easily detected, pain may be due to a periapical abscess or to an unerupted tooth. In case of doubt, radiograms of the teeth should be taken. Pain may also be referred to the face from lesions of the heart and lungs.

Hysterical pain in the face may lead to diagnostic difficulties. It fails to conform to the characters either of trigeminal neuralgia or of any form of pain due to an organic disease, signs of which are absent, nor does it respond to analgesic drugs, often not even to morphine. Other hysterical symptoms may be present, and the patient's mental state usually affords a clue to the nature of the pain.

Prognosis.

Spontaneous recovery from trigeminal neuralgia is extremely rare. The interval between the attacks of pain may be long, remissions lasting months or even years. As a rule, however, once the disorder is established attacks follow each other fairly frequently and the intervals between them tend to become shorter. Finally there may be many attacks during the day.

Treatment.

The first step in treatment is to eliminate as far as possible all *sources of infection within the area of the trigeminal nerve*. It must be confessed, however, that this usually fails to influence the course of the disorder and the wholesale extraction of sound teeth is quite unjustifiable. Medicinal treatment is often effective in controlling the pain and rendering life tolerable in the milder cases. It should, therefore, always be tried. The following mixture is useful:

Potassium bromide	.	.	gr. 10
Tinct. of gelsemium	.	.	♏. 10
Phenazone	.	.	gr. 7½
Water to ½ ounce, thrice daily.			

In severe cases temporary relief may be afforded by a powder containing aspirin, gr. 10, pyramidon, gr. 10, and heroin, gr. 1/10th, but neither heroin nor morphine should be prescribed regularly in view of the risk of habit formation. Trichlorethylene, when inhaled, possesses the peculiar property of causing anaesthesia within the trigeminal distribution and has been found to afford relief in some cases of trigeminal neuralgia. Twenty to twenty-five drops of a chemically pure preparation are poured on to piece of gauze and inhaled through the nose until the odour has disappeared. This should be done three times a day, the patient being recumbent, since giddiness may occur, and care being taken that the liquid does not touch the nose. Trichlorethylene almost always affords some relief from the pain and in some cases the benefit is lasting

If the pain cannot be controlled by medicinal measures, it will become necessary to interrupt conductivity in the fifth nerve. This may be done by alcoholic injections of the nerve at various points or by surgical division of the nerve.

Alcoholic Injection.

The supra-orbital nerve may be injected with alcohol at the supra-orbital notch, the infra-orbital nerve at the infra-orbital foramen; the maxillary nerve, at its point of emergence from the foramen rotundum, the mandibular nerve, at the foramen ovale. Alternatively all three divisions can be reached together at the Gasserian ganglion Injection of the ganglion should theoretically afford longer relief from pain than the injection of the nerves or their branches outside the skull, since in the latter case regeneration of the nerve-fibres occurs and the pain returns as a rule in from one to two years. Since the ganglion cells are situated in the ganglion, their complete destruction should prevent regeneration of the nerve and lead to permanent relief of pain. This happy result, however, frequently fails to follow injection of the ganglion. The ganglion injection possesses the disadvantage that it causes analgesia of the first division, which is rarely the site of pain, and is not uncommonly followed by neuropathic keratitis. Surgical division of the sensory root of the nerve, which is the operation now generally carried out, gives permanent relief from pain but possesses the disadvantage that it requires a surgeon who is experienced in the technique of intracranial surgery. In the best hands it has a mortality rate of less than 1 per cent. The relative advantages of alcoholic injection and surgical division and of the different sites of injection must be considered in each case. When injection has been decided upon, the following would seem the best method of procedure.

When the maxillary nerve is alone involved injection at the

infra-orbital foramen may first be tried. If the first division is affected as well, the supra-orbital nerve can be injected at the same time. If injection of the maxillary nerve at the infra-orbital foramen does not give relief, it should be injected at the foramen rotundum. When the mandibular nerve is alone involved it should be injected at the foramen ovale. When the second, or the first and second, divisions are affected as well as the third, the ganglion should be injected.

Operative division of the sensory root of the nerve should be reserved for cases in which repeated injections have failed to give relief or when the patient is going abroad or for some other reason desires to avoid the necessity for repeated injections.

Methods of Injection. The equipment required for injection consists of a set of needles, a 2 c.c. record syringe, a 2 per cent. solution of novocain, and 90 per cent. alcohol. The best needles for the purpose are Harris's pattern, made by Messrs. Weiss. Four lengths will be required—2½, 3½, 4, and 5 inches. A general anaesthetic is not as a rule required and should be avoided if possible, as it is helpful to have the co-operation of a conscious patient. A quarter of a grain of morphine together with 1/100th grain of hyoscine may be given an hour before the operation.

Injection of the Supra-orbital Nerve.

An ordinary hypodermic needle is suitable for the injection of the supra-orbital nerve, which is injected at the notch by which it issues from the orbit to the scalp. The skin is sterilized with iodine and the notch is then palpated with the left forefinger, which guides the needle as it enters the notch. As the needle enters the nerve the patient experiences a twinge of pain, which radiates over the forehead to the vertex. One or two drops of novocain are now injected, and, if the needle is within the nerve, anaesthesia of the medial half of the forehead rapidly develops. About ten minims of alcohol are then slowly injected.

Injection of the Maxillary Nerve

1. *At the Infra-orbital Foramen.* The maxillary nerve emerges from the infra-orbital foramen beneath the skin of the cheek about a quarter of an inch below the lower margin of the orbit and about one inch from the middle line. The skin in this region is sterilized with iodine, and the skin and subcutaneous tissues are anaesthetized with a few drops of novocain. The smallest Weiss needle is then introduced in the region of the foramen, which is usually found without difficulty, the left forefinger being kept pressed upon the orbital margin to make sure that the needle does not enter the orbit. The

point of the needle is passed into the foramen for about half an inch and one or two drops of novocain are then injected. This should rapidly produce anaesthesia of the upper lip, cheek, side of the nose, and the lower eyelid. When the anaesthesia has developed, the operation is completed by slowly injecting about 1 c.cm. of alcohol into the nerve.

2. At the Foramen Rotundum (Harris) The skin of the cheek is marked at the point where the anterior border of the coronoid process forms an angle with the malar bone above, and another point is marked where the frontal process of the malar bone bends upwards. These points are joined by a straight line, a plane through which perpendicular to the cheek passes through the foramen rotundum. The skin having been painted with iodine, the first point marked, at which the needle is to be introduced, is anaesthetized with novocain. The point of the needle is then introduced at the lower point marked and passed upwards and inwards at an angle of about 40° above the horizontal in the plane indicated. If the direction is correct the point should pass behind the maxilla and entering the pterygo-maxillary fissure should reach the superior maxillary nerve at the foramen rotundum at a depth of 2 or 2½ inches. When the nerve is struck the patient usually complains of pain referred to the side of the nose and upper lip. Two or three drops of novocain solution should now be injected, and if the point of the needle is in contact with the trunk of the nerve slight anaesthesia will develop in the distribution of the second division. When the position of the needle has been thus confirmed a few drops of alcohol are slowly injected. This usually produces a burning sensation on the cheek, lip, and nose, which passes off as more alcohol is injected, which should be done until the burning ceases and the anaesthesia is complete.

Sometimes it is impossible to reach the foramen rotundum in front of the coronoid process when the mandible and maxilla are exceptionally well developed. In such cases an alternative route must be used, the needle being introduced at the point behind the coronoid process used for injection of the third division (see below). The needle is directed forwards at an angle of from 15° to 30° and upwards at an angle of 15°. When its point strikes the external pterygoid plate it should be manipulated forwards until it slips in front of the anterior edge of the plate, when the nerve should be found at a slightly deeper point. The injection is then continued as already described.

Injection of the Mandibular Nerve.

Two routes are available for the injection of the mandibular nerve as it emerges from the foramen ovale—a horizontal lateral approach,

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as practised in this country, especially by Harris, and an ascending anterior approach, recommended by Härtel.

The Lateral Route (Harris). By this route the needle passes beneath the zygoma and through the sigmoid notch of the mandible. Before beginning, the under-surface of the zygoma should be marked on the skin and another line should be drawn from the incisura notch of the ear to the lower border of the ala nasi. *This line normally* corresponds to the lower border of the sigmoid notch. To determine *the vertical plane beneath which the foramen ovale lies, draw a* vertical line downwards from the zygoma one inch in front of the middle of the external auditory meatus. A needle introduced at the point at which the vertical line crosses the line marking the sigmoid notch and pushed inwards and slightly upwards should reach the foramen ovale at a depth of between 4½ and 5 cm. A slightly better line of approach is afforded by introducing the needle a quarter of an inch in front of this point and passing it inwards and slightly upwards and backwards. The skin is sterilized with iodine, and it and the subcutaneous tissues are anaesthetized with novocain. The needle is then introduced in the manner described. In edentulous persons *there may be difficulty in clearing the sigmoid notch, in which case* a dental prop should be placed between the gums. When the point of the needle strikes the mandibular nerve the patient usually, but not always, complains of a stab of pain in the lower lip, chin, tongue, or auricle. One or two drops of novocain solution should now be injected and, if the point of the needle is in the nerve, anaesthesia will develop in its cutaneous distribution. Only when the position of the needle is thus confirmed should alcohol be substituted for the novocain and injected drop by drop up to a total of 1 c cm. At first the injection of alcohol is attended by a burning sensation referred to the distribution of the nerve, but this passes off in a few seconds. *If when the needle is first introduced pain is felt deep in the ear, it* probably indicates that it has been pointed too far backwards and has penetrated the Eustachian tube. On the other hand, if the point of the needle is too low, it may penetrate the pharynx and cause pain in the throat. In either case the needle should be withdrawn slightly and a fresh attempt made. In case of difficulty it is sometimes helpful to direct the needle slightly forwards and downwards so as to strike the external pterygoid plate. The point is then moved backwards until it slips off the posterior edge of the plate, when the *point should be directed upwards and a little farther backwards*, to strike the foramen ovale.

The Anterior Route (Harris's modification of Härtel's method). The middle of the zygoma is marked with a horizontal line and a point marked on this line 1 inch in front of the middle of the external

auditory meatus A line is now drawn downwards from the external angle of the orbit parallel with the middle line as far as the angle of the mouth. A point is marked on this line 1 to 1½ cm. above the angle of the mouth. A line is now drawn through this point up to the lower eyelid in the direction of the pupil when the eye is looking straight forward, and another line from the same point up to the point marked on the zygoma. Both these lines are prolonged downwards. To reach the foramen ovale the needle must be introduced at the point of intersection of the three lines and pushed upwards and inwards in the plane of the line of the zygoma point when seen from the side, and in a plane half-way between the line to the pupil and that to the outer angle of the orbit, when seen from the front The point of the needle will reach the foramen ovale at a depth of from 5 to 7¼ cm., and the ganglion itself at a depth of from 7 to 8¾ cm. A 10 cm. needle is used and the skin sterilized and anaesthetized in the usual way. When there is reason to believe that the point of the needle has entered the mandibular nerve, novocain and alcohol are injected in the same way as when the lateral route is employed In using the anterior route, if the needle is introduced too horizontally it may strike the Eustachian tube, causing pain referred to the deep part of the ear, if too far medially, it may penetrate the pharynx. If it is introduced in the right direction but too deeply, it may pass through the ganglion and enter the subarachnoid space, in which case cerebro-spinal fluid will drip from the needle when the stylet is withdrawn. If the needle is misdirected or introduced too far the necessary correction must be made before novocain is injected. The internal maxillary artery may be injured by either route, in which cases a haematoma rapidly develops. This is of no serious consequence, as the bleeding can be arrested by pressure applied to the cheek.

Injection of the Ganglion.

The method of injecting the ganglion itself is, except for slight modifications, the same as that employed for injecting the mandibular nerve, but if it is desired to inject the ganglion this can be accomplished with greater certainty by the anterior than by the lateral route. If the lateral route is employed it will usually be found that if more alcohol is injected after producing anaesthesia of the mandibular nerve, the first and second divisions will also become anaesthetic, indicating that the alcohol is infiltrating the ganglion. When the anterior route is used, after striking the mandibular nerve the point of the needle is advanced a further 1 cm. to reach the ganglion. Injection of novocain should then produce anaesthesia of all three divisions, and alcohol is then injected into

5. THE SEVENTH OR FACIAL NERVE

ORIGIN, COURSE, AND DISTRIBUTION

The seventh cranial nerve contains motor fibres only, though it is associated in part of its course with a small number of sensory fibres going to the external auditory meatus, with fibres which excite salivary secretion and with others which convey taste impulses from the anterior two-thirds of the tongue. These secretory and gustatory fibres travel in the pars intermedia of Wrisberg. The motor nucleus is situated in the ventral part of the tegmentum of the pons. The fibres which take origin from this nucleus pass backwards in the pons almost as far as the floor of the fourth ventricle, where they form a loop around the nucleus of the sixth nerve before turning forwards to emerge from the lateral aspect of the lower border of the pons, on the medial side of the eighth nerve, from which the seventh is separated by the pars intermedia. The three nerves then pass together from the pons to the internal auditory meatus. Within the petrous portion of the temporal bone the facial nerve occupies the aqueductus Fallopii or facial canal. After passing outwards it turns sharply backwards on the medial side of the middle ear and then downwards behind it to emerge from the skull at the stylomastoid foramen. At the backward turn of the nerve it expands to form the geniculate ganglion which receives the pars intermedia and which contains the ganglion cells of the taste fibres of the chorda tympani. It sends branches to the sphenopalatine and otic ganglia, carrying fibres for the secretion of saliva. Within the facial canal the facial nerve gives off a nerve to the stapedius muscle, and the chorda tympani nerve which carries gustatory fibres to the anterior two-thirds of the tongue. The chorda tympani after crossing the tympanic cavity emerges from the skull by the iter chordae anterius and unites with the lingual nerve, a branch of the mandibular nerve, beneath the external pterygoid muscle. The facial nerve after emerging from the stylomastoid foramen gives branches to the stylohyoid muscle, to the posterior belly of the digastric and the occipital belly of the occipito-frontalis, and then turns forwards to divide within the parotid gland into a number of branches which innervate the muscles of expression, including the buccinator and the platysma.

FACIAL PARALYSIS

Facial paralysis may be due to:

1. A supranuclear lesion involving the pyramidal fibres concerned in voluntary facial movement.

2. A supranuclear lesion involving the fibres concerned in emotional movement of the face—mimic paralysis.

3 Nuclear and infranuclear lesions involving the lower motor neurones.

4 Primary degeneration or disorder of function of the facial muscles.

1. *Facial paralysis due to a supranuclear pyramidal lesion* is distinguished by the fact that movements of the lower part of the face are affected more severely than those of the upper part, and that though voluntary retraction of the angle of the mouth is weak, emotional and associated movements of the face are little, if at all, affected. Reaction of degeneration does not occur in the facial muscles.

2. The occasional occurrence of *weakness or abolition of emotional movements of the face* with retention of voluntary movements, and the escape of the former after pyramidal lesions indicates that the nervous impulses concerned in emotional movement of the face employ a different supranuclear path from the pyramidal tract. This path appears to originate in the frontal lobe, anterior to the precentral convolution, and most cases of mimic facial palsy are due to lesions of the anterior part of the frontal lobe. This dissociated form of facial weakness has also been described as a result of lesions in the neighbourhood of the optic thalamus.

3. *Lesions involving the lower motor neurones* supplying the facial muscles, since they destroy the final common path, affect to an equal extent all forms of facial movement, and as a rule the upper and lower facial muscles are equally weakened. The symptoms of facial paralysis due to lower motor neurone lesions are described in detail in the section dealing with Bell's paralysis. The facial lower motor neurones may be involved by a lesion:

(i) within the pons;

(ii) within the posterior fossa, between the pons and the internal auditory meatus;

(iii) within the temporal bone,

(iv) after emergence from the skull,

(v) they may be the site of neuritis, throughout their length.

(i) *Pontine Lesions.* Massive lesions involving the facial nucleus or the fibres of the facial nerve inevitably affect in addition neighbouring structures. Facial paralysis due to such lesions is, therefore, usually associated with paralysis of the external rectus, or of conjugate ocular deviation to the same side, and often with paralysis of the *ipsilateral jaw-muscles*. There may also be sensory loss due to involvement of the spinal tract and nucleus of the trigeminal nerve and of the spino-thalamic tract, or a pyramidal lesion of the upper and lower limbs on the opposite side. Acute and chronic degenerative lesions of the facial nuclei are likely to involve other

5. THE SEVENTH OR FACIAL NERVE

ORIGIN, COURSE, AND DISTRIBUTION

The seventh cranial nerve contains motor fibres only, though it is associated in part of its course with a small number of sensory fibres going to the external auditory meatus, with fibres which excite salivary secretion and with others which convey taste impulses from the anterior two-thirds of the tongue. These secretory and gustatory fibres travel in the pars intermedia of Wrisberg The motor nucleus is situated in the ventral part of the tegmentum of the pons. The fibres which take origin from this nucleus pass backwards in the pons almost as far as the floor of the fourth ventricle, where they form a loop around the nucleus of the sixth nerve before turning forwards to emerge from the lateral aspect of the lower border of the pons, on the medial side of the eighth nerve, from which the seventh is separated by the pars intermedia. The three nerves then pass together from the pons to the internal auditory meatus Within the petrous portion of the temporal bone the facial nerve occupies the aqueductus Fallopii or facial canal. After passing outwards it turns sharply backwards on the medial side of the middle ear and then downwards behind it to emerge from the skull at the stylomastoid foramen. At the backward turn of the nerve it expands to form the geniculate ganglion which receives the pars intermedia and which contains the ganglion cells of the taste fibres of the chorda tympani. It sends branches to the sphenopalatine and otic ganglia, carrying fibres for the secretion of saliva. Within the facial canal the facial nerve gives off a nerve to the stapedius muscle, and the chorda tympani nerve which carries gustatory fibres to the anterior two-thirds of the tongue. The chorda tympani after crossing the tympanic cavity emerges from the skull by the iter chordae anterius and unites with the lingual nerve, a branch of the mandibular nerve, beneath the external pterygoid muscle. The facial nerve after emerging from the stylomastoid foramen gives branches to the stylohyoid muscle, to the posterior belly of the digastric and the occipital belly of the occipito-frontalis, and then turns forwards to divide within the parotid gland into a number of branches which innervate the muscles of expression, including the buccinator and the platysma.

FACIAL PARALYSIS

Facial paralysis may be due to:

1 A supranuclear lesion involving the pyramidal fibres concerned in voluntary facial movement.

2 A supranuclear lesion involving the fibres concerned in emotional movement of the face—mimic paralysis.

3. Nuclear and infranuclear lesions involving the lower motor neurones.

4. Primary degeneration or disorder of function of the facial muscles.

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2. The occasional occurrence of weakness or abolition of emotional movements of the face with retention of voluntary movements and the escape of the former after pyramidal lesions indicates that the nervous impulses concerned in emotional movement of the face employ a different supranuclear path from the pyramidal tract. This path appears to originate in the frontal lobe, anterior to the precentral convolution, and most cases of mimic facial palsy are due to lesions of the anterior part of the frontal lobe. This dissociated form of facial weakness has also been described as a result of lesions in the neighbourhood of the optic thalamus.

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bulbar motor nuclei. Pontine lesions causing facial paralysis include tumours, syringobulbia, vascular lesions, acute anterior poliomyelitis, Landry's paralysis, and progressive muscular atrophy. Bilateral facial paralysis occasionally occurs as a congenital abnormality, probably due to a failure of development of the facial nuclei, and is then usually associated with congenital ocular palsies.

(ii) *Within the posterior fossa* the proximity of the facial nerve to the pars intermedia and the eighth nerve is responsible for the fact that these nerves usually suffer together. Lesions in this situation, therefore, usually cause deafness and loss of taste in the anterior two-thirds of the tongue, in association with facial paralysis. The commonest such lesions are acoustic neuroma and other tumours in the region of the cerebello-pontine angle, and syphilitic meningitis

(iii) *Within the temporal bone* the facial nerve may be involved in fractures of the skull and is exposed to infections of the middle ear and mastoid, and facial paralysis may be the direct result of spread of infection from the middle ear to the facial canal, or may follow surgical operations on the ear, in which cases the nerve may be merely contused or actually divided or exposed to invasion by the infecting organism. Slowly progressive facial palsy may be caused by an epidermoid within the temporal bone, and is then associated with deafness (Jefferson and Smalley, 1938). Herpes zoster infecting the geniculate ganglion usually causes facial paralysis through secondary involvement of the motor fibres of the nerve (syndrome of Ramsay Hunt). Facial paralysis occurring as a result of lesions within the middle ear is usually associated with loss of taste in the anterior two-thirds of the tongue, as a result of interruption of the fibres of the chorda tympani within the facial nerve, or in its passage through the middle ear. Inflammation of the facial nerve within the stylomastoid foramen is the cause of facial paralysis occurring spontaneously or following exposure to cold and known as Bell's paralysis

(iv) *After leaving the skull* the fibres of the facial nerve may be involved in inflammation from suppurating glands behind the angle of the jaw or in compression by tumours of the parotid gland. They are exposed to traumatic lesions in the face, including compression by forceps during delivery.

(v) *Neuritis of the facial nerve* may occur in encephalitis lethargica, tetanus, and polyneuritis cranialis

4. *Primary degeneration or disorder of function of the facial muscles* is seen in myasthenia gravis, in which the retractors of the angle of the mouth suffer earlier and more severely than the elevators and depressors of the lips, in the facio-scapulo-humeral type of muscular dystrophy, and in myotonia atrophica.

BELL'S PARALYSIS (FACIAL PARALYSIS)

Definition: Facial paralysis of acute onset due to non-suppurative inflammation of the facial nerve within the stylomastoid foramen.

Aetiology and Pathology.

The most plausible explanation of Bell's paralysis is that it is due to an acute inflammation involving the nerve within the stylomastoid foramen. It is uncertain whether the lesion is primarily an acute neuritis, interstitial neuritis, or in the bone, a periostitis. In either case oedema must lead to compression of the nerve-fibres, with resulting paralysis. At first the nerve is swollen, later it is reduced to a fibrous cord (Morris).

Bell's paralysis may occur at any age from infancy to old age. It appears to be most common in young adults, and males are affected more frequently than females.

In some cases no predisposing cause can be found, but not uncommonly there is a history of exposure to chill, for example, riding in a vehicle or sleeping next to an open window. In other cases the paralysis follows an acute infection of the nasopharynx, and in a small proportion of cases it has been shown to be due to the virus of herpes zoster.

Symptoms.

Bell's palsy is almost always unilateral, very rarely bilateral. The onset is sudden and frequently the patient awakens in the morning to find the face paralysed. He or his friends observe that his mouth is drawn to one side. There is frequently pain at the onset, within the ear, in the mastoid region, or around the angle of the jaw.

There is paralysis of the muscles of expression (Figs 16 and 17). The upper and lower facial muscles are usually equally affected and the muscles are paralysed to an equal extent for voluntary, emotional, and associated movements. The eyebrow droops, and the wrinkles of the brow are smoothed out. Frowning and raising the eyebrow are impossible. Owing to paralysis of the orbicularis oculi the palpebral fissure is wider on the affected than on the normal side. Closure of the eye is impossible. Eversion of the lower lid and lack of approximation of the punctum to the conjunctiva impair the absorption of tears, which tend to overflow the lower lid. The nasolabial furrow is smoothed out, and the mouth is drawn over to the sound side. The patient is unable to retract the angle of the mouth or to purse the lips, as in whistling. Owing to paralysis of the buccinator the cheek is puffed out in respiration and food tends to accumulate between the teeth and the cheek. The displacement of the mouth causes
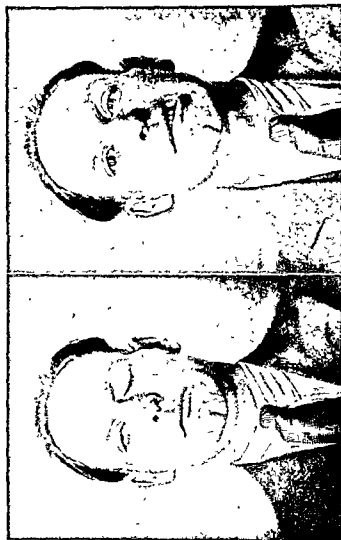
16   17

Figs. 16 and 17. A case of Bell's facial paralysis on the right side. (Note weakness of the orbicularis oculi and of the retractors of the angle of the mouth.)

deviation of the tongue to the sound side when it is protruded and may thus cause paralysis of the tongue to be suspected in error.

When the inflammation spreads up from the stylomastoid foramen to involve the facial nerve above the point at which the chorda tympani leaves it, there is loss of taste on the anterior two-thirds of the tongue, and when the branch to the stapedius is also involved the patient may complain of hyperacusis, an intensification of loud noises.

Diagnosis.

Bell's paralysis of the facial nerve is distinguished from facial paralysis due to a lesion of the pons by the presence in the latter case of symptoms of involvement of other pontine nuclei, especially the fifth and sixth, and sometimes of the long tracts. Lesions in the posterior fossa usually involve the eighth nerve as well. A history of aural discharge and examination of the tympanic membrane makes it easy to recognize facial paralysis secondary to otitis media. Unilateral facial palsy is sometimes an early symptom of disseminated sclerosis, especially in young adults, and is occasionally due to syphilis. A recurrent form associated with headache has been termed 'facioplegic migraine'.

Prognosis.

In most cases of Bell's paralysis complete recovery occurs, though this may take months. If at the end of three weeks from the onset there is some return of voluntary power in the face or some response to faradic stimulation of the facial muscles, recovery is likely to be rapid and will probably be complete in a few weeks. If, however, complete reaction of degeneration has developed, complete recovery is unlikely. In those cases in which recovery is never complete contracture usually develops in the paralysed muscles, and this does much to improve the appearance of the face at rest, although the paralysis is evident when the patient smiles. When marked contracture develops the nasolabial furrow may become actually deeper on the paralysed side than on the normal side and the affected eyebrow may be drawn downwards. Clonic facial spasm is an occasional sequel of incomplete recovery, but usually is not very severe. Recurrent facial palsy is rare. I have known it occur first on one side and a year later on the other.

Treatment.

When the patient is seen during the acute stage treatment should be directed to relieving the inflammation. A small mustard leaf should be applied over the mastoid process and in front of the ear for a quarter of an hour on alternate days, and the ear and face should be kept covered with a pad of wool. A mixture containing

potassium iodide and sodium salicylate should be given. It is sound treatment to try to prevent stretching of the paralysed muscles, which occurs when the mouth is drawn over to the sound side. This may be accomplished by a simple splint made of wire covered with rubber tubing, which is bent round the ear at one end and at the other end forms a hook which fits into the angle of the mouth.

As soon as the acute stage is past and pain has disappeared the galvanic current should be used to stimulate the facial muscle. The negative electrode is held beneath the mastoid and the positive electrode is used to stroke the face, a current of about 3 milliampères being all that is necessary. As soon as voluntary power shows some sign of return the patient should be encouraged to practise closing the eye and retracting the angle of the mouth in front of the looking-glass.

If in six to eight weeks there is no recovery or if reaction of degeneration has set in, surgical treatment should be undertaken. Ballance and Duel's operation of decompression of the Fallopian aqueduct and incision of the nerve sheath gives good results (Morris, 1938, 1939), and has superseded the operation of nerve anastomosis.

FACIAL PARALYSIS COMPLICATING OTITIS MEDIA

Facial paralysis may occur spontaneously in a case of otitis media owing to extension of infection from the middle ear to the facial canal, or it may be a sequel of operation upon the mastoid, at which the nerve may be actually divided or contused or exposed to invasion by the infection. The symptoms are the same as those of Bell's paralysis, and taste is lost on the anterior two-thirds of the tongue. Prognosis is much worse than in Bell's paralysis, however, and in most cases no spontaneous recovery occurs. The outlook is better when the paralysis supervenes two or three days after the operation than when it is an immediate sequel. Recovery, when it occurs, may be long delayed, and hope of improvement need not be abandoned for at least two years.

In view of the poor outlook and the improbability in most cases of even partial recovery, if the response of the facial muscles to faradism is lost the nerve should be explored as soon as possible. If the section cannot be repaired or if a neuroma has developed, Ballance and Duel's operation of introducing a graft from a peripheral cutaneous nerve is carried out. Signs of returning function must not be expected for from six to twelve months after this operation.

CLONIC FACIAL SPASM

Definition· A disorder which chiefly affects middle-aged or elderly women. There are frequent shock-like contractions of the facial muscles, usually limited to one side. Its cause is unknown.

Aetiology and Pathology.

The causation of clonic facial spasm is a matter of hypothesis. It is probably the result of an irritative lesion at some point in the course of the nerve and has been ascribed to a lesion of the geniculate ganglion. Similar spasms certainly occur for a brief period in some cases of herpes zoster of the geniculate ganglion.

Symptoms.

Clonic facial spasm is much more common in women than in men and is rare before middle life. It usually begins in the orbicularis oculi as a fine intermittent twitching resembling that which occurs in normal individuals in states of debility and fatigue and which is known as 'live blood'. The spread of the spasm is extremely slow, but gradually the muscles of the lower part of the face are involved, especially the retractors of the angle of mouth. Finally strong spasms involve all the facial muscles on one side. At this stage there is always slight weakness and wasting of the facial musculature Taste may be lost over the anterior two-thirds of the tongue. Bilateral clonic facial spasm is less common· in such cases one side is usually affected after the other Clonic facial spasm may be associated with trigeminal neuralgia on the same or the opposite side

Diagnosis.

Clonic facial spasm must be distinguished from other involuntary movements involving the face. The commonest of these is habit spasm, a brief compulsive movement usually seen in children and young adults When the face is the site of habit spasm the movements are bilateral. Hysterical blepharospasm, prolonged spasm of the orbicularis oculi, is usually seen in elderly women, and in this case also the movements are bilateral. Myoclonic facial movements may occur unilaterally in encephalitis lethargica, but other signs and symptoms of this disorder are present. The involuntary movements of chorea and athetosis are again bilateral and are associated with similar movements in the limbs

Prognosis.

In the absence of treatment clonic facial spasm is a slowly progressive disorder and spontaneous recovery does not occur. It may terminate in complete facial paralysis on the affected side.

Treatment.

Drugs are of no value. Improvement in some cases follows a course of galvanism applied to the facial muscles and this should

always be tried. If it fails, relief can be obtained by means of a
temporary interruption of conduction in the facial nerve by alcoholic
injection. The method of injection of the nerve-trunk in the region
of the stylo-mastoid foramen is described by Whillis. A selective
paresis can be produced by the simple procedure of injecting with
alcohol the appropriate branches of the nerve as they lie behind the
mandible (Schlosser).

The forefinger is placed between the mastoid process and the
ramus of the jaw, so that the tip lies immediately below the external
auditory meatus   With a skin pencil the level of the tip of the
finger is marked by means of a horizontal line on the cheek in front
of the ear. This line is now intersected by a vertical line marking
the posterior border of the jaw. For purposes of the injection an
ordinary fine hypodermic needle is used with a 1 c cm. syringe. The
point of the needle is introduced at the point of intersection of the
two lines   It is passed inwards until it meets the jaw and then gently
manipulated around the posterior border. The injection should be
made when the point of the needle is immediately behind this. One
or two minims of 2 per cent. novocain solution are first injected and
are followed by a few minims of 90 per cent. alcohol, the needle
being moved slightly upwards and downwards in a vertical plane
during the injection. The effect of the injection is watched by testing
the patient's facial movements while it is being carried out, and the
appropriate degree of paresis can thus be regulated. When the needle
is introduced horizontally at the point indicated, the nerve to the
orbicularis oculi will usually be caught. If it is desired to paralyse
the lower facial muscles the needle must be pointed slightly down-
wards

Alcoholic injection of the branches of the facial nerve gives relief
from the involuntary movements for a period of from six to twelve
months, but they are liable to recur as the muscles recover their
power   To obtain permanent relief Harris and Wright (1932)
recommend facio-hypoglossal anastomosis, but it is wise to observe
the effects of at least one injection of the nerve, which is a very
simple procedure, before having recourse to operation.

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of cases tinnitus is due to a disturbance of the circulation of the internal ear, and this is probably the cause of the tinnitus produced by drugs, for example, quinine, salicylates, and amyl nitrate, by acute labyrinthitis, generalized arteriosclerosis, hyperpiesia, severe anaemia, aortic incompetence, and otosclerosis. Abnormal sounds arising within the cranium may be conducted to the ear and so cause tinnitus. Thus a rhythmical bruit is sometimes heard by the patient in cases of rupture of the internal carotid into the cavernous sinus, congenital intracranial aneurysm, and arterial angioma. Irritation of the auditory afferent paths may lead to tinnitus when the eighth nerve is the site of a tumour or is involved in inflammation due, for example, to syphilitic meningitis. Tinnitus is rarely the result of a lesion of the central nervous system, but may occur in association with deafness after vascular or other lesions of the lateral part of the tegmentum of the pons. Noises heard as a result of irritative lesions of the auditory cortex in the temporal lobe are usually more complex than those caused by irritation of the auditory apparatus and its lower pathways. In this group fall auditory hallucinations comprising the aura of an epileptic fit and those which sometimes occur as symptoms of a neoplasm or other lesion involving the temporal lobe.

The treatment of tinnitus is disappointing. Local lesions of the ear should receive appropriate treatment, and the teeth should be investigated for sources of sepsis. Sedatives such as phenobarbital and bromide usually have some palliative action. In severe cases, in which the tinnitus is intolerable, it may be justifiable to destroy the cochlea or to divide the eighth nerve, but the patient must be informed that complete deafness in the ear thus treated will result and that tinnitus may persist in spite of the operation.

THE VESTIBULAR FIBRES AND THE FUNCTIONS OF THE LABYRINTH

Anatomy.

The part of the labyrinth concerned with equilibrium consists of the semicircular canals, the utricle, and the saccule. The semicircular canals, three in number, are hollows in the petrous part of the temporal bone, the osseous canals, occupied by membranous tubes filled with endolymph and separated from the bony walls by perilymph. They are arranged approximately in three planes of space at right angles to one another, and are so placed that when the head is inclined 30° forwards from the erect position the lateral canal is horizontal. The superior canal lies in a plane midway between the frontal and the sagittal planes with its outermost portion anteriorly, and runs inwards and backwards. The posterior canal lies in a vertical plane at right angles to the superior canal, with its outermost

portion posteriorly, and runs inwards and forwards. Each canal exhibits a dilatation, the ampulla, which contains specialized epithelium, the crista, bearing hair-cells which are the vestibular receptors. Somewhat similar receptors exist in the utricle and saccule, but in these the hair-cells are in contact with small crystals, the otoliths. The semicircular canals are excited by movement and especially angular movement. The precise way in which this stimulates the hair-cells is still unsettled, but the best working hypothesis is that they respond to movement of the endolymph The utricle and saccule convey information concerning the position of the head in space, *the position of the otoliths with reference to the hair-cells varying under the influence of gravity.*

The vestibule and semicircular canals are innervated by the vestibular division of the eighth nerve, the ganglion cells of which are situated in the vestibular ganglion or ganglion of Scarpa. The central fibres of these cells enter the pons, where some end in a series of terminal nuclei, the principal nucleus, the nucleus of the descending tract, the lateral, or Deiters' nucleus, and the superior, or Bechterew's nucleus Other fibres run directly to the cerebellar cortex, especially that of the vermis, by the restiform body The principal connexions of the vestibular nucleus are effected by fibres which leave Deiters' nucleus to join the posterior longitudinal bundle, or descend in the anterior columns of the spinal cord as the vestibulospinal tract.

Stimulation of the Labyrinth.

Stimulation of the labyrinth plays an important part in neurological diagnosis Also it enables us to study under physiological conditions symptoms which result from disease of the labyrinth and its nervous connexions The labyrinth can be stimulated by irrigating the external ear with hot or cold water—the caloric test—by rotating the patient, or by passing a galvanic current through the ear. The first two are the methods in common use, and the caloric test possesses the advantage over rotation that only one labyrinth is stimulated Space does not permit a detailed account of the great variety of observations which can be made by these methods. These are fully described in such books as Isaac H. Jones's *Equilibrium and Vertigo* and the work of Ewill *(1929)*. *All that will be attempted here is to elucidate certain general principles and their practical applications.*

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The Caloric Test.

For simplicity we shall consider the effects of stimulation of the right horizontal semicircular canal. The patient is placed with his

head inclined backwards 60° so that the horizontal canal becomes
vertical, and the right ear is then irrigated with cold water, i.e. water
at a temperature of about 70° F. The effect of cooling the canal is
to cause a current in the endolymph from above downwards in the
patient's present position, or from before backwards with reference
to the normal position of his head. Such a current is the same as that
normally evoked by turning the patient to the left, in which case the
inertia of the endolymph causes it to move backwards in the right
horizontal canal.

Artificial stimulation of the labyrinth evokes movements of the
endolymph such as normally occur only in response to movements
of the head, and as such are normally followed by appropriate
reactions in the eyes, trunk, and limbs. All the reactions to labyrin-
thine stimulation can be interpreted as the appropriate responses
to such a movement as normally causes an endolymph current
similar to that artificially induced by the stimulus. These reactions
consist of (1) vertigo, (2) nystagmus, (3) pass-pointing, and (4) forced
movements, especially falling.

1. *Vertigo.* Movements of the endolymph normally follow move-
ments of the head in space, and contribute to the conscious perception
of such movements By means of a change of temperature in the
semicircular canals, and in other ways, we can induce movements
of endolymph when the head is at rest. Such artificially induced
endolymph currents evoke in the subject an hallucination of move-
ment He feels as if he were experiencing the movement which norm-
ally causes the endolymph current that has been artificially excited;
and at the same time certain motor reactions appropriate to such
a movement are reflexly evoked. The hallucination of movement
derived from the labyrinthine proprioceptors conflicts with the in-
formation derived from the proprioceptors of his muscles and joints
that the subject is sitting in a chair. This conflict of proprioceptor
information causes vertigo. It is most conveniently designated
by the direction of the hallucinated movement, which is in the same
plane as the endolymph current and in the opposite direction.

Vertigo is usually attended by an hallucination of rotation of the
surroundings in the plane of the hallucination of movement but in
the opposite direction.

2 *Nystagmus.* Nystagmus of labyrinthine origin consists of a slow
and a quick phase The former may be regarded as a deviation of the
eyes compensatory to the hallucination of movement evoked by
the movement of the endolymph. Thus in the test just described the
endolymph current is from before backwards in the right horizontal
canal, as if the subject were turning to the left. The slow phase of
the nystagmus is therefore to the right, which is the direction in

which the eyes would require to be moved to keep in view a fixed object in these circumstances. The slow phase is thus in the direction of the endolymph movement. *The quick phase is in the opposite direction.* Its source is uncertain. Nystagmus elicited by stimulation of the horizontal canals is in the horizontal plane; that evoked from the vertical canals is rotary by caloric and rotary or vertical by turning tests. Labyrinthine nystagmus is increased in amplitude when the eyes are deviated in the direction of the quick phase, diminished in the opposite direction

3. *Pass-pointing.* Pass-pointing following labyrinthine stimulation is a compensatory movement in the same sense as the slow phase of the nystagmus The patient is asked to point to the observer's hand with his outstretched arm and index finger. With the eyes closed he is required to move his finger away and bring it back again several times in a vertical or horizontal plane. His arm deviates in the direction of the endolymph movement.

4. *Forced movements* include rotation of the head or of the whole body when the patient is lying in bed, and falling when he stands or attempts to do so These movements are again compensatory to the hallucinated movement and therefore occur in the direction of the endolymph movement

Effect of Changing the Position of the Head upon the Response to Labyrinthine Stimulation.

Information derived from the labyrinthine proprioceptors is referred to the whole body Thus the subject of labyrinthine stimulation experiences an hallucination that his whole body and not his head only is turning. This is the explanation of the effects of changing the position of the head upon the response to labyrinthine stimulation. For example, if an endolymph current from before backwards is induced in the right horizontal canal with the head erect, the subject experiences an hallucination of turning to the left and the resulting forced movement is rotation to the right. If now the head is thrown back 60°, the horizontal canal and its endolymph current lie in the coronal plane of the body, the hallucinated movement is in this plane to the left, and the subject falls in this plane to the right. If, instead, the head is bent forwards 120°, *the direction of the endolymph is reversed relative to the body and the subject falls* to the left.

Methods of Stimulating the Labyrinth.

Caloric Tests. As already described, the right horizontal semi-circular canal is stimulated by irrigating the external ear with cold

water (at 70° F.) with the head extended 60°, and the resulting nystagmus is horizontal with the quick phase to the left. With the head thrown forward 120° the endolymph current induced by cold water is in the opposite direction, and the nystagmus is horizontal and the quick phase is to the right. With the head in the normal upright position the vertical canals are stimulated, and the nystagmus is rotary and the quick phase is to the left. Irrigation with warm water (at 110° F.) causes an endolymph current in the opposite direction to that evoked by cold water, and these effects are all reversed. Irrigation of the left ear produces the opposite effects to irrigation of the right. In normal individuals douching with warm or cold water elicits nystagmus in forty seconds and both nystagmus and vertigo last on an average for twenty-six seconds

Rotation Tests The labyrinth may also be stimulated by rotating the patient On rotation to the right the inertia of the endolymph causes it to move away from the ampulla in the left, and towards the ampulla in the right, horizontal semicircular canal. As rotation continues the endolymph 'catches up' the canal and the two are mutually at rest. If, now, the rotation is suddenly stopped the momentum of the endolymph causes it to continue moving in the same plane, that is, in the opposite direction to its original movement It now moves towards the ampulla in the left canal and away from it in the right, *as if* the subject were rotating to the left. This causes nystagmus in the horizontal plane with the quick phase to the left The vertical canals may be stimulated by rotating to the right with the head extended 60° or flexed 120° or lying on the right shoulder In the first two instances the nystagmus is rotary, with the quick phase to the right and left respectively; in the last it is vertical, with the quick phase downwards. Rotation to the left produces the opposite effects. The usual rotation test is to turn the patient ten times in one direction at a rate of one turn in two seconds, and the resulting nystagmus and vertigo normally last forty seconds. It is believed that the movement of endolymph towards the ampulla is twice as effective a stimulus as the movement away from the ampulla After rotation to the right with the head erect, two-thirds of the response is excited by the left and one-third by the right horizontal canal

The table on p. 183 shows the principal responses to the different methods of stimulating the labyrinth, which can be expressed in the following rule. The slow phase of the nystagmus, pass-pointing, and falling are in the direction of the endolymph movement; the quick phase of the nystagmus and the vertigo are in the opposite direction.

Table showing Responses to Labyrinth Stimulation

(Irrigation with warm water causes opposite effects to irrigation with cold
water; rotation to left, opposite effects to rotation to right.)

Stimulus	Position of Head	Nystagmus (Quick Phase)	Vertigo (Hallucination of Movement).
Irrigation of right ear with cold water at 70° F.	Erect	Rotary to left	Falling to left in frontal plane
	Extended 60°	Horizontal to left	Turning to left.
	Flexed 120°	Horizontal to right	Turning to right.
Rotation to right	Erect	Horizontal to left	Turning to left.
	Extended 60°	Rotary to right	Turning to left, but, on moving head to erect position, falling to right in frontal plane.
	Flexed 120°	Rotary to left	Turning to left, but, on moving head to erect position, falling to left in frontal plane
	Flexed 90° on right shoulder	Vertical downwards	Turning to left, but, on moving head to erect position, falling forwards.

The Diagnostic Value of Labyrinth Tests.

Labyrinth tests yield information concerning (1) the sensitivity of the labyrinth, (2) the conductivity of the eighth nerve, and (3) the integrity of the cerebral paths concerned in nystagmus of labyrinthine origin, pass-pointing, and vertigo.

Lesions of the internal ear and eighth nerve usually involve the cochlear as well as the vestibular functions, hence some degree of deafness is present. Tinnitus also suggests a labyrinthine lesion. Such lesions, moreover, proportionately impair the functions of both vertical and semicircular canals, and, since the lesion is on the common afferent path of the reflex arcs, nystagmus, pass-pointing, and vertigo are diminished to an equal extent. The characteristic findings in disease of the labyrinth or eighth nerve are either an absence of response to stimulation on the affected side, or a response which only appears after longer stimulation and is of shorter duration than normal. Vertigo, nystagmus, pass-pointing, and falling show an equal degree of impairment. Occasionally over-excitability is found.

A central lesion is suggested by a normal cochlea and insensitive canals, normal sensitiveness of horizontal, and impaired responses from vertical, canals, or vice versa, and a dissociated loss of vertigo, pass-pointing, or nystagmus, one response being absent but not the others.

Special attention has been devoted to labyrinth tests in neuroma of the acoustic nerve, in which it is claimed that the typical findings are an insensitive labyrinth, with deafness on the side of the lesion and a loss of reactions from the vertical canals but not from the horizontal canal on the opposite side. The dissociated loss is attributed to pressure by the neuroma upon the pons where the decussated fibres from the opposite vertical canals lie more superficially than those from the horizontal canal.

VERTIGO

The Nature of Vertigo.

Vertigo may be defined as the consciousness of disordered orienta-tion of the body in space. The derivation of the term implies a sense of rotation of the patient or of his surroundings, but this, though frequently present, is not the only form of vertigo as just defined. There are three ways in which the spatial orientation of the body may be felt to be disordered.

1. The external world may appear to move, often in a rotatory fashion, but other forms of movement, such as oscillation, may be experienced

2 The body itself may be felt to be moving, either in rotation or as a sensation of falling, or the movement may be referred to within the body, e g within the head.

3 The postures and movements of the limbs, especially the lower limbs, are felt to be ill adjusted and unsteady.

The motor accompaniments of vertigo consist of forced movements of the body, such as falling, and disordered orientation of parts of the body, manifested in the eyes as nystagmus and sometimes diplopia, and in the limbs as pass-pointing, while visceral disturbances, such as pallor, sweating, alterations in the pulse-rate and blood-pressure, nausea, vomiting, and diarrhœa may be present. Temporary amau-rosis and even loss of consciousness may occur in severe attacks.

Since vertigo is due to a disturbance of spatial orientation, a brief review of the organization of this function is desirable. The main-tenance of an appropriate position of the body in space depends in man upon several groups of afferent impulses, of which the following are the most important.

1. From the retinæ are derived visual impulses which in con-tributing to our perception of visual space are intimately concerned in spatial orientation.

2. Equally important are impulses derived from the proprioceptors of the ocular muscles. The degree of accommodation and ocular convergence required to produce a sharply focused image of an object upon the maculae conveys information as to its distance from the eyes, and the state of contraction or relaxation of the external ocular muscles in conjugate ocular deviation contributes data to our recognition of 'above', 'below', 'to the right of', and 'to the left of'.

3. The labyrinth is a highly specialized spatial proprioceptor. The otoliths are mainly concerned in the orientation of the organism with reference to gravity, while the semicircular canals respond to movement and to angular momentum.

4. The proprioceptors of the joints and muscles of the neck are of importance in relating labyrinthine impulses, which convey information solely concerning the position of the head, to the attitude of the rest of the body

5. The proprioceptors of the lower limbs and trunk are concerned with the position of the body in relation to the acts of sitting, standing, and walking.

The afferent impulses derived from these various sense-organs are mutually related by central mechanisms, of which the cerebellum, the vestibular nuclei, the posterior longitudinal bundle, and the red nuclei are probably the most important, and which constitute reflex paths by which the position of the body is normally appropriately orientated. From these lower centres impulses reach the cerebral cortex probably in the parietal lobe and so influence voluntary movement. Vertigo may result from the disordered function either of the sensory end-organs or of the afferent paths or of the central mechanisms concerned.

The Causes of Vertigo.

It is clear from the anatomical and physiological considerations outlined above that vertigo may be the result of a disturbance of function at many different levels. We may therefore recognize (1) psychogenic vertigo, (2) vertigo due to cortical disturbances, (3) vertigo of ocular origin, (4) vertigo of cerebellar origin, (5) vertigo due to brain-stem lesions, (6) vertigo due to lesions of the eighth nerve, and (7) aural vertigo. In diffuse conditions, such as head injury and circulatory disease, it may be impossible to say what is the site of origin of the symptoms.

(1) Psychogenic Vertigo.

'Giddiness' is a common symptom among sufferers from anxiety neurosis. There is no sensation of rotation but the symptom consists of a feeling of instability associated with a sense of anxiety and the

symptoms of over-activity of the sympathetic nervous system.
Vertigo may also occur as a conversion symptom in hysteria.

(2) *Vertigo due to Cortical Disturbances.*

The aura of an epileptic attack may be a feeling of giddiness, as
is not uncommon in petit mal. Vertigo may also occur in migraine
and in association with localized cerebral lesions. It may be caused
by an intracranial tumour in any situation.

(3) *Vertigo of Ocular Origin.*

Vertigo may occur in normal individuals in consequence of unusual
vision perceptions. Giddiness at heights and on looking from the
platform at a swiftly moving train are examples of this. Paralysis
of one or more external ocular muscles is often associated with
vertigo. This is due to the spatial disorientation which is produced
by false projection of the visual fields (see p. 66).

(4) *Vertigo of Cerebellar Origin.*

Vertigo may be slight or absent in spite of a massive lesion of
the cerebellum, especially if this be limited to the lateral lobe. A
cerebellar lesion is most likely to cause vertigo when it involves
the inferior vermis which is closely linked anatomically with the
vestibular system. Thus severe vertigo may occur at the onset of
thrombosis of the posterior inferior cerebellar artery.

(5) *Vertigo due to Brain-stem Lesion.*

Vascular or neoplastic lesions of the brain-stem may cause vertigo
if they involve the vestibular connexions. A plaque of disseminated
sclerosis in the pons may cause severe vertigo with conspicuous
nystagmus, vomiting, and prostration: so too may syringobulbia.

(6) *Vertigo due to Lesions of the Eighth Nerve.*

Since the eighth nerve carries the vestibular fibres, lesions of this
nerve may cause giddiness associated with deafness and tinnitus.
The commonest such lesion is an acoustic neuroma, but the nerve
may also be compressed by abnormal vessels or involved in inflam-
mation in meningitis or meningo-vascular syphilis.

(7) *Aural Vertigo.*

The agencies which may cause vertigo by disturbing the functions
of the labyrinth are numerous. They include (1) wax in the external
auditory meatus, (2) blockage of the Eustachian canal and sudden
changes in atmospheric pressure, (3) acute and chronic suppurative
otitis media, (4) otosclerosis, (5) drugs, especially quinine and the
salicylates, (6) impairment of blood supply due to atheroma with or

without high blood-pressure, vasomotor instability, severe anaemia and increased intracranial pressure, (7) *herpes zoster* of the geniculate ganglion, (8) acute non-suppurative labyrinthitis, (9) recurrent aural vertigo (Ménière's syndrome), (10) sea- and air-sickness.

Acute Labyrinthitis.

Acute labyrinthitis is usually due to an extension of purulent infection from the middle ear. A rare spontaneous form of acute lesion of the labyrinth has received the name 'acute serous labyrinthitis'. Deafness, usually rapidly progressive, is associated with the symptoms of acute vestibular disturbance, vertigo, and nausea and vomiting, nystagmus, forced movements, and ataxia of the limbs on the affected side. There is also pain in the ear and often considerable pyrexia. The symptoms are those of irritation of the affected labyrinth. The patient lies on the sound side and pass-points and falls to the side of the lesion. Nystagmus is rotary and the quick phase is to the opposite side, to which the patient feels he is falling. Meningitis and intracranial abscess may complicate purulent labyrinthitis. In the serous form some recovery both of cochlear and of vestibular function may occur.

RECURRENT AURAL VERTIGO (MÉNIÈRE'S SYNDROME)

Definition: Recurrent aural vertigo is a syndrome probably of varied aetiology. The characteristic feature is the recurrence of attacks of severe giddiness leading to vomiting and prostration and usually associated with tinnitus and *increasing deafness*. The disorder runs a protracted course with a tendency to disappearance of the vertigo as the deafness increases. All the characteristics of recurrent aural vertigo were described by Ménière (1860–1).

Aetiology and Pathology.

Men suffer from recurrent aural vertigo more often than women in a proportion of about 3 to 2. It is a disorder of middle age, especially late middle age, the average age of onset being 49, and more than one-third of all patients are first affected after the age of 60. Little is certainly known about the aetiology. Focal sepsis in the teeth, tonsils, and nasal sinuses is certainly important in some cases. Abnormalities of water metabolism have been emphasized by Mygind and Dederding. The affinity between recurrent aural vertigo and migraine was first pointed out by Ménière himself. Allergy may possibly be a common basis in some cases.

Recent pathological investigations by Hallpike and Cairns (1938) have demonstrated a gross dilatation of the endolymph system of the internal ear in two cases, in one of which there was a chronic non-

suppurative otitis media. On the other hand, in some cases recurrent aural vertigo may be due to pressure upon the eighth nerve by an abnormal vessel (Dandy).

Symptoms.

Usually deafness and tinnitus which develop insidiously precede vertigo, the onset of which is sudden. In some cases the giddiness develops so rapidly that the patient may fall; more often it takes a few minutes to become severe. In a severe attack the patient is literally prostrated and there is an intense sensation of rotation of the surroundings, less often of the patient himself. Vomiting soon develops with severe nausea and lasts as long as the patient remains giddy. Sometimes there is also diarrhœa. The pulse may be rapid or slow and the blood-pressure raised or lowered and there may be profuse sweating. Double vision may occur, and in very severe cases consciousness may be lost. Deafness and tinnitus are sometimes intensified during the attack. The vertigo may last from half an hour to many hours and then gradually subside. On attempting to stand and walk the patient is unsteady and staggers.

During the attack the patient usually lies on the sound side and exhibits a rotary nystagmus which is most evident on looking towards the affected ear. Exceptionally the attack is of the otolithic type—a sudden fall not preceded by giddiness. In the intervals between the attacks giddiness is liable to be brought on by sudden movements of the head and there is often a fine rotary nystagmus on extreme lateral fixation to either side. There may be some persistent unsteadiness as indicated by an inability to stand steadily with the eyes closed or to walk heel-and-toe. Deafness may be unilateral or bilateral. Both air and bone conduction are usually impaired and there is a selective loss of the higher tones.

Diagnosis.

Aural vertigo may sometimes be confused with petit mal, but when giddiness is a symptom of minor epilepsy the attacks last only a few seconds, consciousness is always impaired or lost and the giddiness disappears as rapidly as it develops. In Ménière's syndrome tinnitus and some impairment of hearing are almost always present, and a lesion which involves both the cochlear and the vestibular functions must be situated either in the internal ear or in the eighth nerve. A lesion in the latter situation almost always interferes with the functions of the facial nerve, and often of the fifth and sixth nerves on the same side as well as of the cerebellum. When vertigo is due to lesions of the brain-stem or cerebellum hearing is unimpaired and other symptoms of lesions in these situations are usually present.

Prognosis.

The attacks tend to recur at irregular intervals and with varying severity. Usually the intervals of freedom last only a few weeks; in rare cases the patient is free from attacks for years. There is a tendency for the attacks to diminish in severity spontaneously and finally cease *pari passu* with an increase of the deafness. Exceptionally, in the absence of radical treatment, the attacks continue for many years.

Treatment.

During an attack the patient must rest lying perfectly still. An intravenous injection of 1–2 c.cm. of pernocton or a subcutaneous injection of a $\frac{1}{4}$ gr. of morphia with 1/100th gr. of hyoscine hydrobromide will relieve the discomfort in severe cases. The best prophylactic is $\frac{1}{2}$ gr. of phenobarbital two or three times a day. Small doses of quinine and strychnine are sometimes helpful. A careful search for focal sepsis in the teeth, tonsils, or nasal sinuses should be carried out and any infection found appropriately treated. A salt-free diet combined with a restriction of fluid intake may be helpful. Ammonium chloride in doses of 30 grains three or four times a day can also be tried. If, after six months, the patient shows no response to medical measures, and especially if the vertigo incapacitates him from following his occupation, surgical treatment should be considered. The choice then lies between the injection of alcohol into the internal ear and intracranial division of the vestibular fibres of the eighth nerve.

SEA- AND AIR-SICKNESS

Definition. A disturbance of visceral function, leading in severe cases to vomiting, vertigo, and severe prostration, evoked by repeated movement of the body in unaccustomed planes.

Aetiology.

The same physiological disturbance underlies both sea- and air-sickness. A ship at sea is capable of a variety of different movements, depending upon the direction of the waves in relation to its motion. In addition to the lifting and falling movements of the whole ship oscillatory movements occur about an axis within the ship. Pitching is such a movement in the fore-and-aft plane, and rolling is a lateral movement. A corkscrew movement may result from a combination of roll and pitch. The way in which these abnormal movements cause sea-sickness has been the subject of much discussion. There is evidence that abnormal stimulation of the labyrinth is the most important factor, though other

contributory factors are present. A life on land accustoms most individuals to all types of movement which occur in the plane of the horizontal semicircular canals. The vertical canals, however, are rarely excited by movements of the body as a whole. The movements of a ship in a rough sea cause an irregular excitation of the vertical canals which leads to a disorder of equilibrium until the subject has adapted himself to it. This adaptation is rendered the more difficult by the disturbance of his appreciation of visual space which results from the movement of the ship relative to himself and of both relative to the horizon, and by the occurrence of ocular imbalance, which is probably secondary to the disorganization of the labyrinthine impulses. As we have seen, vertigo, however produced, is often associated with reflex disturbances of the autonomic nervous system, and these are probably the main cause of the vomiting of sea-sickness, though the frequent alterations in the position of the abdominal contents in relation to gravity may be a contributory factor. When the patient is already nauseated and hypersensitive to olfactory stimuli it is not surprising that the smells inseparable from a ship and from association with other victims should reinforce the vestibular and ocular stimuli.

Susceptibility to sea-sickness varies in different individuals. The very young and very old are often immune and so, too, are deaf-mutes with inactive labyrinths. Many years at sea usually confer a relative immunity, but some never acquire even this. An individual who has become adapted to the movements of one type of ship is liable to become sea-sick when transferred to another vessel. Suggestion based upon past unhappy experiences is a potent predisposing factor.

Symptoms.

Symptoms occur in the following order of frequency (Maitland): vomiting, nausea alone, headache, vertigo, abdominal discomfort, vomiting without nausea, lassitude, and blurred vision. Sea-sickness may lead to overaction either of the sympathetic or of the para-sympathetic divisions of the autonomic nervous system. Hence the patient may exhibit either a rise in blood-pressure and an increase in the pulse-rate or a fall in blood-pressure with bradycardia. Pallor, sweating, or flushing and dilatation of the pupils are common. Ketosis may occur.

Diagnosis.

The diagnosis is not usually in doubt, but it is important to distinguish from true sea-sickness a neurotic reaction which may begin as soon as the patient goes on board, and also sickness occurring at sea but due to other disorders.

Prognosis.

Sea-sickness is never fatal, but in severe cases leads to extreme prostration, from which recovery may be slow. Most individuals adapt themselves to the movements of the ship and recover spontaneously in a few days. A few remain sea-sick as long as they are at sea.

Prophylaxis and Treatment.

The objects at which to aim are to diminish the sensitivity of the labyrinth and to limit as far as possible the patient's exposure to the movements of the ship which stimulate the vertical canals. Susceptible individuals should take ½ gr. of phenobarbital twice or three times a day as a vestibular sedative two or three days before embarking and should continue this treatment for the first few days of the voyage. If vomiting occurs, a patient with a slow pulse is likely to respond best to drugs of the belladonna group, such as 20–30 minims of the tincture spread over four hours, or 1/100 gr. of hyoscine hydrobromide, or benzedrine in doses of 10 mg. If the *pulse is rapid* phenobarbital, bromide, chloral or tincture of opium in 30-minim doses is more likely to be effective. When on board the patient should consult his preferences as to whether he remains on deck or retires to his cabin. When the ship is pitching he should lie athwart the vessel; when it is rolling he should lie fore-and-aft. Closure of the eyes, wearing coloured glasses, or bandaging one eye may be helpful. The diet for a day or two before going on board and during the early days of the voyage should be light and digestible. Plenty of sugar should be taken to diminish the tendency to ketosis and an alkaline mixture may be given with the same object, and, since constipation is apt to be troublesome, this may conveniently take the form of an effervescent saline purgative.

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7. THE NINTH OR GLOSSOPHARYNGEAL NERVE

The glossopharyngeal nerve contains both sensory and motor
fibres. The ganglion cells of the former are situated in the ganglion
petrosum of the nerve. Their central processes mostly pass into the
tractus solitarius and terminate in the nucleus of this tract. A few
also enter the dorsal nucleus of the vagus. The motor fibres originate
partly in the inferior salivatory nucleus and partly in the nucleus
ambiguus. The glossopharyngeal nerve arises by a series of radicles
from the posterior lateral sulcus of the medulla in line with the
fibres of origin of the vagus and spinal accessory nerves. After
crossing the posterior fossa of the skull it emerges through the
anterior compartment of the jugular foramen. In the neck it arches
downwards and forwards between the internal carotid artery and the
internal jugular vein and then between the internal and external
carotid arteries to the side of the pharynx. Within the skull it gives
off the tympanic branch which enters the tympanic cavity to which
it supplies sensation, and joins the tympanic plexus, from which the
small superficial petrosal nerve carries to the otic ganglion fibres
which excite salivary secretion. In the neck the glossopharyngeal
nerve gives a branch to the stylopharyngeus muscle, its sole motor-
supply, and branches to the mucous membrane of the pharynx. The
terminal branches of the nerve supply the tonsil, the lower bor-
der and posterior surface of the soft palate, and the posterior third
of the tongue. The glossopharyngeal nerve is thus the motor nerve of
the stylopharyngeus and carries fibres concerned in the secretion of
saliva, especially by the parotid gland. It supplies common sensi-
bility to the posterior third of the tongue, the tonsils, and the
pharynx, and taste-fibres from the same region.

Isolated lesions of the glossopharyngeal nerve are almost unknown. It is most frequently damaged in association with the vagus and spinal accessory nerves at the jugular foramen (see below).

GLOSSOPHARYNGEAL NEURALGIA

The glossopharyngeal nerve is occasionally subject to paroxysmal neuralgia, which in its general characteristics resembles the much commoner paroxysmal trigeminal neuralgia. We owe the recognition of this syndrome to Harris. As in trigeminal neuralgia, the pain occurs in brief attacks, which may be of great severity. It usually begins in the side of the throat and radiates down the side of the neck in front of the ear and to the back of the lower jaw. Exceptionally, the pain may begin deep in the ear. Attacks tend to be precipitated by swallowing or by protruding the tongue, and the ear may be extremely sensitive to touch.

Glossopharyngeal neuralgia is *distinguished from trigeminal neuralgia by the situation of the pain and the precipitation of the attacks by swallowing* Pain of a similar distribution may occur as a result of new growths involving the tonsil and pharynx, and this cause must therefore be excluded In glossopharyngeal neuralgia there is often a long history of pain

As in trigeminal neuralgia, treatment consists in interruption of the afferent fibres of the nerve. Harris has successfully injected the nerve with alcohol after its emergence from the skull, but this is a difficult procedure and does not reach the fibres of the tympanic nerve which leave the glossopharyngeal within the skull. To obtain *permanent relief it is better to carry out surgical avulsion of the nerve*, which may be performed in the neck when the pain is predominantly pharyngeal, but should be carried out intracranially in the posterior fossa when the deep part of the ear also is the site of pain (Jefferson).

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8. THE SENSE OF TASTE

There are only four tastes: sweet, salt, bitter, and acid. All other flavours are olfactory sensations.

The sense of taste is tested by means of weak solutions of sugar, common salt, quinine, and acetic acid or vinegar. While the sense of taste is being tested the patient must keep his tongue protruded and must reply to questions by nodding or shaking his head. It is convenient to have the names of the four tastes written on cards to which he can point. The protruded tongue is dried and a drop of the testing solution applied to the lateral border on one side. The patient is then asked to indicate what he tastes. The anterior two thirds and the posterior one-third of the tongue must be tested separately. The tongue is dried between successive tests.

THE TASTE FIBRES

Peripheral Path.

The peripheral path of the taste fibres is still a matter of controversy. Their usual route is probably as follows.

The fibres carrying taste impulses from the anterior two-thirds of the tongue pass at first through the lingual nerve to the chorda tympani, through which they reach the facial nerve and the geniculate ganglion which contains their ganglion cells. From the geniculate ganglion they pass to the pons by the pars intermedia of Wrisberg. In certain cases alcoholic injection of the Gasserian ganglion and third division of the trigeminal nerve at the foramen ovale has been followed by loss of taste on the anterior two-thirds of the tongue, though this loss is often only temporary. It is possible that the loss of taste in such circumstances is not due to an interruption of the taste fibres but to secondary trophic effects on the tongue of the lesion of the mandibular nerve. On the other hand, it has been suggested that the taste fibres after reaching the geniculate ganglion by the route already described pass by the small superficial petrosal nerve to the otic ganglion and ultimately reach the pons through the third division of the fifth nerve.

Taste fibres from the posterior one-third of the tongue, from the pharynx, and from the lower border of the soft palate are carried by the glossopharyngeal nerve.

Central Connexions.

The taste fibres after entering the pons pass into the tractus solitarius, the upper part of which, sometimes called the gustatory nucleus of the trigeminal, may receive taste fibres from the trigeminal nerve, while the middle part receives fibres from the pars intermedia

and the lower part fibres from the glossopharyngeal. The fibres of the tractus solitarius terminate in a column of grey matter known as the nucleus of this tract, from which relay neurones arise, which cross the midline and turn upwards in the tegmentum of the pons and medulla to form the gustatory fillet, which lies near the midline, to the outer side of the posterior longitudinal bundle. The gustatory fillet ascends to the optic thalamus, from which taste fibres are further relayed to the hippocampus major, the cortical centre for taste.

LOSS OF TASTE

Loss of taste—ageusia—on the anterior two-thirds of the tongue *may occur as a result of lesions of the chorda tympani or of the geniculate ganglion* and in some cases of the mandibular nerve. There is no clear evidence as to whether or not it results from lesions of the pars intermedia. Lesions of the glossopharyngeal nerve cause loss of taste on the posterior one-third of the tongue. Lesions of the tractus solitarius and its nucleus cause unilateral ageusia, and lesions near the middle line of the pons may cause bilateral loss of taste from destruction of both gustatory fillets (Harris)

Little is known with regard to loss of taste resulting from cerebral lesions, *though taste is occasionally lost, together with the sense of smell, as a result of head injury*

Hallucinations of taste may occur in association with those of smell as a result of an irritative lesion involving the uncinate gyrus. Lesions in this region may also cause parageusia, a perversion of taste in which many substances excite the same unpleasant flavour.

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9. THE TENTH OR VAGUS NERVE

CENTRAL CONNEXIONS

The vagus nerve contains both sensory and motor fibres The ganglion cells of the former are situated in the ganglion jugulare and in the ganglion nodosum of the nerve. The cells of the ganglion jugulare are concerned in the supply of common sensibility to part of the external ear and terminate in relation with the spinal tract of the trigeminal nerve and its nucleus. The cells of the ganglion nodosum are concerned in the carriage of afferent impulses from the pharynx, larynx, trachea, oesophagus, and the thoracic and abdominal viscera. *Their central processes terminate in relation with*

paralysis. Unilateral paralysis of the pharynx as a rule causes no symptoms. On examination the pharyngeal wall droops on the affected side and the pharyngeal reflex is present only on the normal side Bilateral pharyngeal paralysis causes marked dysphagia and bilateral loss of the pharyngeal reflex. In such cases soft, pulpy foods, such as porridge, are more readily swallowed than solids and liquids

PARALYSIS OF THE LARYNX

The motor fibres to the larynx originate in the lowest part of the nucleus ambiguus and some at least probably leave the medulla by the accessory fibres of the spinal accessory nerve, subsequently joining the vagus in the jugular foramen. The fibres destined for the crico-thyroid muscle, which acts as a tensor of the vocal cords, leave the vagus by the superior laryngeal nerve and reach the muscle through its external branch. Fibres which innervate the abductors and adductors of the vocal cords leave the vagus by the recurrent laryngeal nerves

Movements of the Vocal Cords.

Abduction of the vocal cords occurs during inspiration, and the cords are adducted in phonation and coughing Reflex adduction occurs in response to irritation of the larynx.

Supranuclear Lesions.

Little is known regarding the occurrence of paralysis of the larynx as a result of supranuclear lesions. Hemiplegia does not impair the movement of the vocal cords. Bilateral lesions involving the laryngeal centre in the cortex at the base of the precentral convolutions may do so (Horsley). In such cases respiratory and reflex laryngeal movements are unaffected.

Nuclear and Infranuclear Lesions.

The following varieties of laryngeal paralysis may occur:

Unilateral Total Paralysis.

In this condition there is a paralysis both of abduction and of adduction of the vocal cord which lies in the intermediate or cadaveric position This may occur as a result of a unilateral lesion at any point between the nucleus ambiguus and the recurrent laryngeal nerve inclusive. Phonation is not abolished, since the normal cord crosses the middle line to meet the paralysed one, but there is usually some hoarseness and difficulty in coughing. Dyspnoea and inspiratory stridor are absent

Unilateral Abductor Paralysis.

This is usually the result of a unilateral lesion of the recurrent laryngeal nerve. The affected vocal cord lies at, or close to, the middle line and fails to abduct on inspiration   Phonation and coughing are unaffected, and there is no dyspnœa, though slight inspiratory stridor may occur.

Bilateral Total Paralysis.

This may be produced by bilateral lesions at any point between the nucleus ambiguus and the recurrent laryngeal nerves inclusive Both cords are paralysed in the cadaveric position   Phonation and coughing are lost.   There is no dyspnœa, but inspiratory stridor may occur on deep inspiration.

Bilateral Abductor Paralysis.

This may occur as a result of nuclear lesions or of bilateral lesions of the recurrent laryngeal nerves   There has been much discussion as to why a lesion of the recurrent laryngeal nerve, which innervates both abductors and adductors, should sometimes cause paralysis of abductors only, and no adequate reason for this has been proposed. In bilateral abductor paralysis both cords lie close together at or near the middle line and fail to abduct on inspiration   The voice is little affected and coughing is normal, but owing to the failure of abduction there is severe dyspnœa, with marked inspiratory stridor. The dyspnœa may necessitate tracheotomy.

Bilateral Adductor Paralysis.

This is usually hysterical. The cords are not adducted in phonation, which is therefore lost, and the patient can only whisper. Adduction occurs, however, in coughing, which is unaffected. Dyspnœa and stridor are absent.

Visceral Functions of the Vagus.

Little is known concerning the effects of lesions of the vagus upon its visceral functions.   In animals section of both vagi is usually fatal.   In man compression of one vagus nerve in the neck causes slowing of the heart beat, and tachycardia may follow bilateral lesions of the vagus, for example, in the case of subtentorial tumours and in *diphtheritic and alcoholic polyneuritis.*

LESIONS INVOLVING THE VAGUS

Nuclear Lesions.

Lesions of the nucleus ambiguus may occur in posterior inferior cerebellar thrombosis, syringobulbia, medullary tumour, progressive

paralysis. Unilateral paralysis of the pharynx as a rule causes no symptoms. On examination the pharyngeal wall droops on the affected side and the pharyngeal reflex is present only on the normal side. Bilateral pharyngeal paralysis causes marked dysphagia and bilateral loss of the pharyngeal reflex. In such cases soft, pulpy foods, such as porridge, are more readily swallowed than solids and liquids

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Unilateral Abductor Paralysis.

This is usually the result of a unilateral lesion of the recurrent laryngeal nerve. The affected vocal cord lies at, or close to, the middle line and fails to abduct on inspiration. Phonation and coughing are unaffected, *and there is no dyspnoea, though slight inspiratory stridor may occur.*

Bilateral Total Paralysis.

This may be produced by bilateral lesions at any point between the nucleus ambiguus and the recurrent laryngeal nerves inclusive. Both cords are paralysed in the cadaveric position. Phonation and coughing are lost. There is no dyspnoea, but inspiratory stridor may occur on deep inspiration.

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LESIONS INVOLVING THE VAGUS

Nuclear Lesions.

Lesions of the nucleus ambiguus may occur in posterior inferior cerebellar thrombosis, syringobulbia, medullary tumour, progressive

muscular atrophy, encephalitis lethargica, acute anterior polio-myelitis, rabies, Landry's paralysis, and diphtheritic and other forms of polyneuritis.

Nuclear lesions usually cause an associated paralysis of the soft palate, pharynx, and larynx, though when the upper part of the nucleus only is affected the larynx escapes (palato-pharyngeal paralysis syndrome of Avellis)

Bilateral abductor paralysis of the larynx may be due to a nuclear lesion, of which the commonest cause is tabes. It may also occur as a symptom of plumbism.

Lesions in the Posterior Fossa.

Lesions which involve the vagus between its emergence from the medulla and its exit from the skull in the jugular foramen almost invariably affect neighbouring cranial nerves, especially the ninth, eleventh, and twelfth. Such lesions include tumours and syphilis and the extension of infection from the middle ear to the bone or dura mater of the posterior fossa. The commonest combinations of associated cranial nerve lesions in this region are glossopharyngeal, vagus, and spinal accessory (the syndrome of the jugular foramen and of Vernet); vagus and spinal accessory (the syndrome of Schmidt); vagus, spinal accessory, and hypoglossal (the syndrome of Hughlings Jackson).

Lesions of the Trunk.

Lesions of the trunk of the vagus above the origin of the superior laryngeal nerve cause unilateral anaesthesia of the larynx, with total paralysis of the ipsilateral vocal cord.

Lesions of the Recurrent Laryngeal Nerve.

Lesions of the recurrent laryngeal nerve do not affect the sensibility of the larynx They may cause total paralysis of the larynx or paralysis of abduction. The left recurrent laryngeal nerve, owing to its longer course, is more exposed to damage than the right. Within the thorax it may be compressed by aneurysm of the aorta, and rarely by the enlarged left auricle in mitral stenosis, or by neoplasm of the mediastinum or enlargement of mediastinal glands due to neoplastic metastases, lymphosarcoma, or Hodgkin's disease. Within the neck both recurrent laryngeal nerves are exposed to trauma, to the pressure of enlarged deep cervical glands, whether malignant or inflammatory, and of an enlarged thyroid, and may be involved in carcinoma of the oesophagus.

The Superior Laryngeal Nerve.

Lesions of this nerve are of no importance, but the nerve may require to be injected with alcohol, at the point where the internal laryngeal branch pierces the thyrohyoid membrane, for the relief of pain due to tuberculosis of the larynx.

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10 THE ELEVENTH OR SPINAL ACCESSORY NERVE

Origin and Distribution

The spinal accessory is a purely motor nerve, which arises partly from the medulla and partly from the spinal cord. The accessory portion, or *internal* branch, is derived from cells of origin which are situated in the lower part of the nucleus ambiguus of the medulla The spinal portion, or external branch, is derived from cells situated in the lateral part of the anterior horn of grey matter of the spinal cord, from the first cervical down to the fifth cervical segment. The accessory fibres emerge from the lateral aspect of the medulla below the roots of the vagus nerve. The spinal fibres emerge from the lateral aspect of the spinal cord between the anterior and posterior roots. The spinal rootlets unite to form a trunk, which ascends in the spinal subdural space, posterior to the ligamentum denticulatum, to the foramen magnum, where it joins the accessory portion to form a single trunk, which leaves the skull through the jugular foramen in the same compartment as the vagus In the jugular foramen the accessory fibres join the vagus, and their subsequent course to the pharynx and larynx has already been described. The spinal portion, or external branch, enters the neck between the internal carotid artery and the internal jugular vein. Passing downwards and laterally across the latter it descends beneath the sternomastoid muscle, which it supplies as it pierces it on its deep aspect. After crossing the posterior triangle the nerve ends by entering the trapezius on its deep surface. In its course it communicates with branches of the second, third, and fourth cervical nerves.

Nuclear Lesions.

Lesions of the nucleus ambiguus, the nucleus of origin of the accessory fibres, have been described in the section dealing with the vagus nerve. The cells of origin of the spinal fibres in the anterior horns of the grey matter of the upper five cervical segments may undergo degeneration in acute anterior poliomyelitis and progressive muscular atrophy, or may be compressed in syringomyelia or by tumours involving the spinal cord in the cervical region.

Lesions of the Nerve-trunk.

Within the posterior fossa the nerve-trunk may be damaged by the pressure of tumours, by syphilis, and by the spread of infection from the middle ear, usually suffering in association with neighbouring cranial nerves, especially the ninth, tenth, and twelfth, as described in the section on the vagus nerve. After emerging from the skull the nerve-trunk may be compressed or involved in inflammation by the upper deep cervical glands, or may be severed by operations in this region. When the lesion is deep to the sternomastoid, both sternomastoid and trapezius are paralysed; when it is in the posterior triangle of the neck the sternomastoid escapes.

LESIONS OF THE SPINAL BRANCH

Unilateral Lesions.

Paralysis of one sternomastoid causes no abnormality in the position of the head at rest. The muscle is wasted and is less salient than its fellow on the normal side. There is weakness of rotation of the head to the opposite side, and when the patient flexes the neck the chin is slightly turned to the paralysed side by the unopposed action of the normal opposite muscle. A lesion of the spinal accessory nerve causes paralysis of only the upper fibres of the trapezius. This part of the muscle is wasted and the normal curve formed on the back of the neck by the lateral border of the trapezius becomes flattened. The shoulder is lowered on the affected side and the scapula becomes rotated downwards and outwards, the lower angle being nearer the midline than the upper. There is also slight winging of the scapula, which disappears when the serratus magnus is brought into action. There is weakness of elevation and retraction of the shoulder, and the patient is unable to raise the arm above the head after it has been abducted by the deltoid. It can still be raised above the head in front of the body, however, a movement in which the serratus magnus takes part.

Bilateral Lesions.

Bilateral paralysis of the sternomastoids causes weakness of flexion of the neck, and the head tends to fall backwards when the patient is erect. Weakness of the sternomastoids is conspicuous in myotonia atrophica. Paralysis of both trapezii causes weakness of extension of the neck, and the head tends to fall forwards. This is most frequently seen in progressive muscular atrophy and in myasthenia gravis.

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11   THE TWELFTH OR HYPOGLOSSAL NERVE

Origin and Distribution

The hypoglossal nerve is the motor nerve of the tongue. Its fibres originate in the hypoglossal nucleus of the medulla, which represents an upward continuation of the anterior horn of grey matter of the spinal cord. It is an elongated column of grey matter which in its upper part is subjacent to the floor of the fourth ventricle, near the midline, and below is situated on the antero-lateral aspect of the central canal. The nerve-fibres after leaving the nucleus pass forwards through the medulla to emerge from its ventral aspect between the olive and the pyramid. After a short course across the posterior fossa the rootlets of the nerve unite in the anterior condylar foramen through which it leaves the skull. In the neck the nerve passes downwards and forwards towards the hyoid bone and then turns medially towards the tongue, passing forwards and downwards over the two carotid arteries, lying beneath the digastric and stylohoid muscles It then passes between the mylohoid and hyoglossus muscles to reach the tongue.

The chief branch of the hypoglossal nerve, its descending branch, passes downwards in the anterior triangle to join the descending cervical nerve and form the ansa hypoglossi, from which branches are distributed to the majority of the infrahyoid muscles. A further branch of the hypoglossal nerve supplies the thyrohyoid muscle but the fibres which leave the nerve by both the descending and the thyrohyoid branch are derived from a communication from the first and second cervical nerves.

Lesions of the Hypoglossal Nerve

A unilateral lesion of the hypoglossal nerve causes weakness and wasting, with reaction of degeneration of the corresponding half of

the tongue. The wasting of the tongue muscles throws the epithelium on the affected side into folds, and owing to the relative thickening of the epithelium fur tends to accumulate on the paralysed half of the tongue. The median raphe becomes concave towards the paralysed

FIG 18. Paralysis and wasting of the right side of the tongue, due to a lesion of the right hypoglossal nerve. (Note the deviation of the tongue to the paralysed side on protrusion.)

side, to which the tip is deviated. The tongue deviates to the paralysed side on protrusion (Fig. 18). Unilateral paralysis of the tongue does not impair articulation.

Bilateral lower motor neurone lesions of the tongue cause marked wasting of both sides, associated, when the lesion is due to a progressive degeneration of the cells of the nuclei, with fibrillation. In severe cases of bilateral paralysis the tongue lies in the floor of the mouth and protrusion is impossible. Dysarthria and some degree of dysphagia are present, but bilateral paralysis of the tongue is not

usually an isolated phenomenon, and in such cases these symptoms are therefore due in part to paralysis of other muscles.

Unilateral lesions of the tongue may occur as a result of lesions involving the hypoglossal nucleus or the fibres of the nerve in their course through the medulla, for example, acute poliomyelitis, syringobulbia, and thrombosis of median branches of the vertebral artery. In the last case one or both pyramidal tracts are usually also involved. Between the medulla and the anterior condylar foramen the nerve-roots may be compressed by a tumour or by an aneurysm of the vertebral artery, or may be involved in syphilitic meningitis, or by extension of infection from the middle ear to the basilar bone or to the dura mater overlying it. In such cases the glossopharyngeal, vagus, and spinal accessory nerves are likely to suffer in association with the hypoglossal (syndrome of Hughlings Jackson)

Unilateral hypoglossal paralysis has been ascribed to a periostitis of the anterior condylar foramen analogous to the lesion of the stylomastoid foramen responsible for Bell's facial paralysis. It is a rare sequel of nasal injury In the neck the nerve may be injured in operations in this region, accidentally or intentionally, as in the operation of hypoglosso-facial anastomosis Hemiatrophy of the tongue may occur as part of the syndrome of facial hemiatrophy

The commonest cause of a bilateral lower motor neurone lesion of the tongue is involvement of the medullary nuclei in progressive muscular atrophy—progressive bulbar palsy. In such cases fibrillation is conspicuous as long as active degeneration is occurring

There should be no difficulty in distinguishing upper from lower motor neurone lesions involving the tongue Bilateral upper motor neurone paralysis occurs as a result of lesions involving both pyramidal tracts above the medulla and forms part of the syndrome known as pseudo-bulbar palsy. The commonest causes are double hemiplegia of vascular origin, disseminated sclerosis, amyotrophic lateral sclerosis, and tumours of the brain-stem. The tongue is somewhat smaller than normal owing to spastic contraction of the muscles, but true wasting does not occur and the reaction of degeneration is absent. Neighbouring muscles are also the site of spastic paralysis and the jaw-jerk is exaggerated.

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CHAPTER III

HYDROCEPHALUS AND INTRACRANIAL TUMOUR

1. HYDROCEPHALUS

Definition: An increase in the volume of the cerebro-spinal fluid within the skull.

Aetiology.

It is important at the outset to distinguish (1) increase in the volume of cerebro-spinal fluid without increase in its pressure, and (2) increase in the volume with increase in that pressure.

(1) *Increase in the volume of the cerebro-spinal fluid without increase of pressure* is of no clinical importance. In such cases the excess of fluid is compensatory to atrophy of the brain, and this condition is observed in cases of congenital cerebral hypoplasia and of acquired cerebral atrophy due to diffuse sclerosis, general paralysis, and senile or presenile degenerative changes. There is an excess of fluid occupying the subarachnoid space over the shrunken convolutions, and there is also usually some distension of the cerebral ventricles, which, however, is not due to increased intraventricular pressure but is a passive result of atrophy of the white matter of the hemispheres.

(2) *Increased volume of the cerebro-spinal fluid with increased pressure* is due to a disturbance of the formation, circulation, or absorption of the fluid. In some cases one, in others more than one, of these factors operate.

As we have seen in a previous section, the cerebro-spinal fluid is formed by the choroid plexuses of the cerebral ventricles, flows through the ventricular system, reaches the subarachnoid space by the foramina of Luschka, bathes the surface of the brain and spinal cord, and is resorbed into the blood-stream by the arachnoid villi of the intracranial venous sinuses and possibly also by the capillaries of the nervous system.

Increased Formation.

We know little about causes of increase in the rate of formation of the cerebro-spinal fluid. Bedford's work renders it unlikely that hydrocephalus can be caused by obstruction of the great vein of Galen Increased formation of fluid occurs, however, when the osmotic tension of the blood is lowered as in meningism. It is probable that reflex hyperaemia of the choroid plexuses causes increased formation of the cerebro-spinal fluid in meningitis, and increased permeability may occur in toxic states and after head injury

Obstructed Circulation.

Obstruction to the circulation of the cerebro-spinal fluid may occur at any point of its course. Within the ventricles the commonest cause is a neoplasm which may compress one or both foramina of Monro, or fill the third ventricle. The aqueduct of Sylvius may be obstructed by a tumour arising in the third ventricle, in the midbrain, or in the pineal body, or may be congenitally absent. Owing to the small calibre of the aqueduct of Sylvius, slight swelling of its ependymal lining may lead to its obstruction, and cases have been reported in which hydrocephalus has followed ependymitis in this region

Subtentorial tumours may obstruct the fourth ventricle The foramina of Luschka may be blocked by adhesions following meningitis or by displacement of the medulla into the foramen magnum by the pressure of a tumour. Within the subarachnoid space obstruction may again be due to tumour, to adhesions following trauma, inflammation, or haemorrhage, or to congenital abnormalities.

Among the last-named is the Arnold-Chiari malformation. This is a tongue of cerebellar tissue with an elongated medulla oblongata which protrudes into the spinal canal. Russell and Donald (1935) suggest that the malformation prevents the cerebro-spinal fluid from flowing upwards into the cerebral subarachnoid space and so interferes with its absorption. This abnormality is associated with meningomyelocele and lumbo-sacral spina bifida, or sometimes with simple meningocele. To remove the sac in such cases of spina bifida may precipitate hydrocephalus if this is not present already, because, it is suggested, the sac is capable of absorbing some cerebro-spinal fluid.

Impaired Absorption.

Absorption of fluid from the arachnoid villi may be impaired by a rise in the intracranial venous pressure, due to compression of venous sinuses by an intracranial tumour, or impediment to the venous drainage from the head by raised intrathoracic pressure in cases of pulmonary neoplasm, aneurysm of the aorta, or severe emphysema. Thrombosis of the superior longitudinal sinus by extension of infection from the lateral sinus seems the probable cause of the condition described as 'otitic hydrocephalus' in which symptoms of hydrocephalus complicate otitis media or mastoiditis (Symonds 1931, 1937). (See also p. 318.) Obliteration of the arachnoid villi by inflammatory material may occur in meningitis.

We can thus distinguish the following varieties of hydrocephalus:

(1) Increased volume of cerebro-spinal fluid with normal pressure—compensatory hydrocephalus.

(2) Increased volume of cerebro-spinal fluid with increased pressure
—*hypertensive hydrocephalus.*

Hypertensive hydrocephalus can be further subdivided, as Dandy
has shown, into

(i) *Obstructive hydrocephalus,* in which there is an obstruction to
the circulation of the cerebro-spinal fluid, either within the ventricles
or at the outlet from the fourth ventricle, which prevents free com-
munication between the ventricles and the subarachnoid space, and

(ii) *Communicating hydrocephalus,* in which free communication
between the ventricles and the subarachnoid space exists and
hydrocephalus is due either to disturbance in the formation and
absorption of cerebro-spinal fluid, or to an obstruction to its circula-
tion in the subarachnoid space itself.

In obstructive hydrocephalus pressure within the lateral ventricles
differs from that in the spinal subarachnoid space, determined by
lumbar puncture when the patient is in the horizontal position, and
the pressure of the fluid in the latter position is often not raised
and may be subnormal. Moreover, a dye injected into the ventricles
cannot be recovered from the spinal subarachnoid space after an
interval of five minutes, as is normally the case.

In communicating hydrocephalus the intraventricular and spinal
subarachnoid pressures are the same when the patient is horizontal,
and both are above normal. Free communication between the
ventricles and the spinal subarachnoid space is indicated by the
rapid passage of the dye from the former to the latter.

The terms internal and external hydrocephalus are incompletely
descriptive, since the ventricles are usually dilated in all forms
of hydrocephalus, both compensatory and hypertensive, and an
increased volume of fluid in some parts of the subarachnoid space
is common to both compensatory and hypertensive communicating
hydrocephalus.

Hypertensive hydrocephalus may be either congenital or acquired.
The congenital variety may be developed before birth, the enlarged
head forming an obstruction to labour. It is due to congenital mal-
development of the circulatory channels at some point and is often
associated with other congenital abnormalities, such as spina bifida,
hare lip, and club foot. In a few recorded cases a familial tendency
has been observed. Other cases of so-called congenital hydro-
cephalus may be due, as Cushing suggests, to head injury at birth,
the arachnoid villi, through which the absorption of cerebro-spinal
fluid occurs, becoming blocked by the coagulation of extravasated
blood in the subarachnoid space. Acquired hydrocephalus has been
divided into 'primary' and 'secondary' varieties. This distinction
has some clinical value as indicating that in some cases the hydro-

cephalus is a symptom of a clinically recognizable intracranial lesion, while in others the cause remains obscure. Pathologically, however, the term 'primary hydrocephalus', like 'idiopathic epilepsy', is merely an expression of our ignorance.

The commoner causes of acquired hydrocephalus are adhesions of the leptomeninges following meningitis, thrombosis of the intracranial venous sinuses, and intracranial tumour, especially when situated in the posterior fossa. Syphilitic meningitis is a rare cause. Sheldon and others have reported cases of ependymitis of the aqueduct of Sylvius leading to its obliteration and causing hydrocephalus. Obstruction within the fourth ventricle or in the subarachnoid space is occasionally due to parasitic cysts.

Pathology.

As we have seen, the causes of hydrocephalus are pathologically various, and they need not be described in detail. Distension of the cerebral ventricles is the most conspicuous feature. When obstruction occurs in the aqueduct of Sylvius only the lateral and third ventricles are distended. When the obstruction is more caudally situated the aqueduct of Sylvius and the fourth ventricle may also be enlarged *Ventricular distension causes thinning of the cerebral hemispheres*, which in severe cases may be extreme and is associated with some atrophy of the cortical ganglion cells *The ependyma of the ventricles is normal, except in inflammatory cases, when a localized or more or less diffuse ependymitis may be present. Meningeal adhesions indicate a previous meningitis* Distension of the ventricles leads to pressure upon the bones of the skull, which become thin, especially where they overlie the cerebral convolutions. Separation of the sutures occurs when hydrocephalus develops in early life, but is not as a rule seen after the age of 18. Compression of the base of the skull causes erosion of the clinoid processes and excavation of the sella turcica. The olfactory tracts and optic nerves are usually atrophic.

Symptoms.

Congenital Hydrocephalus

Enlargement of the head is the most conspicuous symptom in congenital hydrocephalus (Fig 19). It may occur before birth, but is usually noticed during the first few months of life In most cases it is slowly progressive and the head may attain a huge size, with a circumference of 30 inches or even more. The cranial sutures are widely separated and the anterior fontanelle is much enlarged There is marked congestion of the veins of the scalp. In extreme cases the head may be translucent and may yield a fluid thrill on percussion and an audible murmur on auscultation. Enlargement of the head

P

occurs in all its diameters. The frontal region bulges forwards, and downward pressure upon the orbital plates causes the eyes to be protruded forwards and downwards. Owing to the expansibility of the skull in infancy, the familiar symptoms of increased intracranial pressure are slight or absent. Hydrocephalic children seem little troubled by headache and rarely vomit. Convulsions are com-

Fig 19 Enlargement of the head due to congenital hydrocephalus.

mon. Bilateral anosmia may occur. Optic atrophy due to pressure upon the nerves is usually present, but in some cases there is papilloedema, and this may be imposed upon optic atrophy. Visual acuity is progressively reduced until in severe cases the child becomes blind Paralysis of other cranial nerves may occur, and squint is not uncommon. Nystagmus may be present. In the limbs there are usually some weakness and inco-ordination, which is generally more marked in the lower than in the upper limbs. Spasticity with exaggeration of tendon reflexes is common in the lower limbs, though sometimes the tendon reflexes are lost. The plantar reflexes *are usually extensor. There is little or no disturbance of sensibility.* The mental state varies in different cases. In severe cases there is usually mental deficiency, but in milder cases this may be slight or absent. In milder cases there may be obesity due to compression of the hypothalamus and pituitary gland. In more severe cases there is usually wasting Cerebro-spinal rhinorrhoea is a rare complication.

Acquired Hydrocephalus.

The clinical picture of acquired hydrocephalus varies somewhat with its cause. In obstructive hydrocephalus symptoms of increased intracranial pressure are conspicuous. Headache and vomiting are the earliest symptoms and are followed after a short interval by the development of papilloedema. *The headache is at first paroxysmal*, but later becomes constant, and there are sometimes intense exacerbations characterized by severe headache radiating down the neck and associated with head retraction and even with opisthotonos, vomiting, and impairment of consciousness. Giddiness is a common symptom. Some mental deterioration usually occurs after a time, especially in later life, and hallucinations, delusions, and disturbances of emotional mood may occur. Convulsions are less common in the acquired than in the congenital variety. Enlargement of the head is less conspicuous in acquired than in congenital hydrocephalus, on account of the greater age of the patient, and does not occur after the age of 18. Before that age there is often slight separation of the cranial sutures, yielding a 'cracked-pot sound' on percussion and associated with venous congestion of the scalp. Cranial nerve palsies may occur, especially paralysis of the sixth and seventh nerves, and often fluctuate in severity from day to day. Slight exophthalmos *is not uncommon. Gross weakness of the limbs is absent, though* clumsiness and slight inco-ordination are common. The tendon reflexes may be exaggerated or diminished. The plantar reflexes are frequently extensor. There is as a rule no sensory loss. Symptoms of hypopituitarism, obesity, and genital atrophy, are common in children and adolescents.

In 'otitic hydrocephalus' due to thrombosis of the superior longitudinal sinus papilloedema is usually conspicuous, but headache and vomiting and other signs are often slight or even absent.

The pressure of cerebro-spinal fluid is increased in communicating hydrocephalus, but is usually normal or may be diminished in obstructive hydrocephalus. The fluid is usually normal in composition. Radiograms of the skull (Fig. 20) may show enlargement of the *calvarium, with thinning, and exaggeration of the convolutional* markings. Separation of the sutures may be present. The clinoid processes are often eroded and the sella turcica is deepened and *expanded antero-posteriorly.*

Ventriculograms show enormous dilatation of the ventricular system (Figs. 21 and 22).

Diagnosis.

The diagnosis of congenital hydrocephalus is not usually difficult. Owing to the enlargement of the head it may be confused with

rickets, but in rickets the enlargement of the head is due to localized thickening of the bone and other characteristic bony abnormalities are present elsewhere.

Acquired hydrocephalus is frequently present as a complication of conditions causing increased intracranial pressure. The recognition
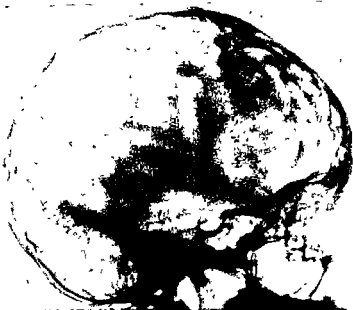

Fig 20 A rise of intracranial pressure has caused great increase in the convolutional markings There is separation of the sutures especially well illustrated in the region of the coronal suture and the junction of the basisphenoid. There is general thinning of the skull. A child suffering from a stricture of the aqueduct of Sylvius. (Radiogram by Dr. Jupe)

of the existence of hydrocephalus is usually a simple matter. The discovery of its cause may be difficult. It is often necessary to determine whether the hydrocephalus is of the obstructive or of the communicating variety. The following tests may be of value in settling this point:

1. *Manometry.* Ventricular and lumbar puncture are performed and a cerebro-spinal manometer is attached to each needle. Normally, when the patient is horizontal, the pressure of cerebro-spinal fluid recorded by the two manometers is approximately the same and slightly raising or lowering the head or the buttocks alters the two pressures in such a way that the upper level of the fluid in the

manometers remains at about the same horizontal level. A marked difference between the ventricular and lumbar pressures when the patient is horizontal indicates obstructive hydrocephalus.

2. *Encephalography.* If air be injected into the lumbar subarachnoid space by the method described on p. 240, with the patient in a sitting position, some normally enters the cerebral ventricles. A failure to introduce air into the ventricles by this method is suggestive, but not conclusive, evidence of obstructive hydrocephalus.

3. *Dye Tests.* Ventricular puncture is performed and 1 c.cm. of neutral phenolsulphonephthalein is injected into one lateral ventricle. Lumbar puncture is then performed, and normally the dye appears in the cerebro-spinal fluid of the lumbar sac in from three to eight minutes. Fluid containing the dye yields a red colour on the addition of 25 per cent. sodium hydroxide solution. The failure of the dye to appear in the lumbar fluid after ten minutes indicates an obstruction to the outflow from the ventricles.

The above tests will help to indicate whether the hydrocephalus is due to a defect in circulation or absorption of the cerebro-spinal fluid. When the cause of the hydrocephalus is a tumour it is rare for focal signs of the tumour to be lacking, though in hydrocephalus of long standing confusion may arise from the presence of signs produced by the hydrocephalus itself. When no focal intracranial cause can be discovered careful inquiry should always be made for a history of otitis and other possible causes of intracranial sinus thrombosis. Spina bifida should suggest the presence of the Arnold-Chiari malformation.

Prognosis.

In most cases congenital hydrocephalus proves fatal during the first four years of life. When the enlargement of the head is rapid the patient is not likely to survive more than one or two years. Exceptionally the disorder becomes arrested and a state of equilibrium is reached between the formation and the absorption of the cerebro-spinal fluid. In those who survive, mental deficiency, epilepsy, and blindness are common. The prognosis of acquired hydrocephalus depends upon its cause and how far this is amenable to treatment.

Treatment.

Congenital Hydrocephalus.

In spite of many and varied attempts to deal surgically with congenital obstructive hydrocephalus the results of treatment have always been disappointing. Treatment has been directed to permitting the escape of fluid from the distended ventricles. Probably it has failed because the channels of absorption are defective.

Openings have been made in the corpus callosum and in the floor of the third ventricle. Dandy has exercised the choroid plexuses of the lateral ventricles. The results of surgical treatment hardly justify its use in such cases, but the Arnold-Chiari abnormality may be successfully treated by suboccipital decompression.

Fig. 21.

FIGS 21 and 22. Hydrocephalus. ventriculograms showing enormous dilatation of the ventricular system, the lateral and third ventricles being clearly seen. The anterior end of the third ventricle has encroached on the pituitary fossa so that the dorsum sellae is eroded and the whole fossa deepened.
(Radiograms by Dr. Jupe.)

Diuretin has been administered in doses of 0.2 gramme thrice daily in order to diminish the formation of cerebro-spinal fluid, and X-ray irradiation of the choroid plexuses has been employed for the same purpose. Otherwise treatment is symptomatic.

Acquired Hydrocephalus.

The appropriate treatment of acquired hydrocephalus depends upon its cause. When it is due to an intracranial tumour this must receive appropriate surgical treatment. In cases of congenital and acquired narrowing of the aqueduct of Sylvius attempts have been made to dilate this channel from its lower end. Obliteration of the

foramina of Luschka by adhesions following meningitis has been successfully treated by Dandy, who constructed a new foramen. Communicating hydrocephalus without a focal intracranial lesion, such as may follow otitis media, or may occur spontaneously, should be treated by repeated lumbar puncture, together with the
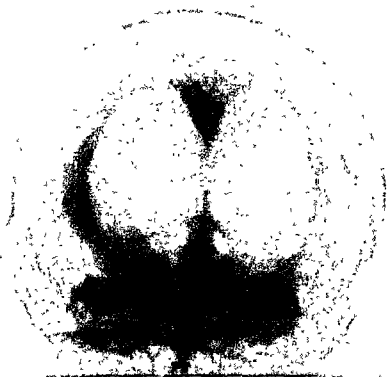

FIG. 22 (see opposite).

administration of magnesium sulphate by the mouth and restricted fluid intake. At each lumbar puncture the pressure of the fluid should be determined, in order that progress may be estimated. Medical treatment may safely be continued as long as visual acuity is not deteriorating. If this occurs as a result of papilloedema, sub-occipital decompression should be carried out.

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2. INTRACRANIAL TUMOUR

Definition: The term 'intracranial tumour' is conveniently applied to localized intracranial lesions, whether of neoplastic or of chronic inflammatory origin, which by occupying space within the skull tend to cause a rise in intracranial pressure.

AETIOLOGY

Apart from those of inflammatory origin, the aetiology of intracranial tumours is little understood. In a minority of cases congenital abnormality appears to play an important part in causation, especially in the angiomatous malformations and the angioblastomas, the ganglioneuromas, the cholesteatomas, and tumours of the cranio-pharyngeal pouch The causation of the gliomas is as obscure as that of neoplasms in general. It is uncertain whether the primitive character of the cells of which some gliomas are composed should be regarded as an indication that they are derived from embryonic cell rests or should be considered as a cellular regression. There is no evidence that trauma is a predisposing factor, except, rarely, in the case of meningiomas which have been known to arise beneath the site of a previous head injury.

An intracranial tumour may occur at any age, though, as will be seen later, certain types of glioma tend to exhibit a characteristic age-incidence. The frequent occurrence of some forms of glioma in childhood is responsible for the fact that the age-incidence of intracranial tumours differs from that of most other malignant neoplasms, which are rare before middle life. Tuberculomas appear to be relatively more common in childhood than in adult life.

Intracranial tumour affects both sexes with equal frequency.

Pathology

The pathology of intracranial neoplasms has made great advances during the present century, chiefly owing to the researches of Cajal, Hortega, and Cushing and his pupils, and has assumed considerable clinical importance. It has been learned that the different types of tumour, even the different varieties of glioma, often exhibit a characteristic age-incidence and rate of growth and a predilection for certain situations in the brain. Hence it is becoming possible for the clinician with increasing frequency to diagnose not only the presence and situation of an intracranial tumour, but also its precise pathological nature, and to form an accurate estimate of its prospects of removal, of the peculiar difficulties likely to be encountered in the task, and of its probable malignancy. Histological examination *during and after removal of the growth, especially in the case of the gliomas*, throws further light on the last point and yields information as to the prospects of a recurrence and the likelihood that the tumour will respond favourably to irradiation therapy, and increasing experience enables the surgeon to some extent to anticipate the results of histological examination from the naked-eye appearance of the neoplasm.

The following figures indicating the relative frequency of the various kinds of intracranial tumour are based upon the findings of Cushing and upon the data obtained from the National Hospital, Queen Square, by Walshe (1931). The percentages are about the same in the two groups with the exception of those referring to pituitary adenoma.

|			
Glioma	.	about 41·0 per cent.	
Meningioma .	.	,, 13·0	,,
Auditory nerve tumour .	,, 10·0	,,
Hypophyseal duct tumour	,, 7·0	,,
Sarcoma	.	,, 7·0[1]	,,
Secondary carcinoma	.	,, 5·0	,,
Pituitary adenoma	.	,, 4·6[1]	,,
,, ,,		,, 19·2[2]	,,
Tuberculoma } Granuloma }	.	,, 2·5	,,
Blood-vessel tumour	.	,, 1·7	,,
Choroid plexus tumour less than	1·0	,,
Cholesteatoma	.	,, ,, 1·0	,,

Gliomas.

The gliomas are tumours derived from the cells which constitute the supporting tissue of the nervous system, but unlike connective-

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[1] National Hospital figures.   [2] Cushing's figures.

tissue tumours elsewhere they are of epiblastic origin. The precise classification of the gliomas is still unsettled. Bailey and Cushing (1926) have proposed a classification based upon the development of the glial cell. In the embryo the medullary epithelium of which the neural tube is composed first differentiates into three types of cell the neuroblast, the primitive spongioblast, and the medulloblast. The neuroblast ultimately develops into the neurone and the primitive spongioblast gives rise to the ependymal cells and the glial cells, with the exception of the microglia which is of mesodermal origin. The medulloblast, it is suggested, preserves the undifferentiated character of the medullary epithelium in that it can develop into either glial or neuronic cells. Bailey and Cushing have recognized in the different types of glioma predominant cells which, they consider, correspond with the various embryonic or mature cell types. This developmental classification is best illustrated by the diagram below, modified by Walshe from Bailey and Cushing.
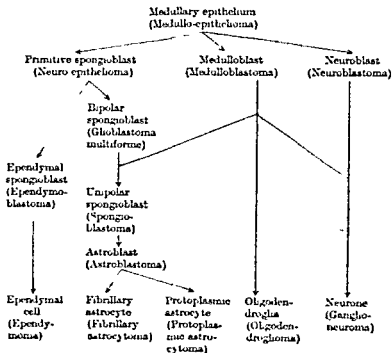
It has been objected that a glioma may contain cells characteristic of different stages of development, and it is probable that Bailey and Cushing's classification is to some extent artificial. Nevertheless,

it is likely that its underlying principle will form a basis of whatever classification is finally adopted. For clinical purposes the following are the most important of the gliomas. Those most frequently encountered are the astrocytomas, about 36 per cent., spongioblastomas, about 34 per cent , and the medulloblastomas, about 11 per cent , of Bailey and Cushing's series of gliomas
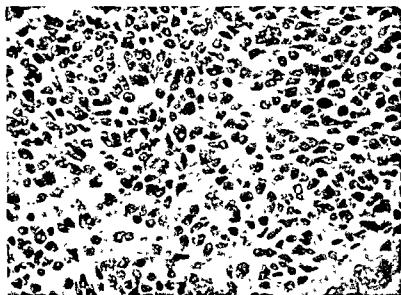

FIG. 23 Medulloblastoma. H. E. ×350

1. *Medulloblastoma* These are rapidly growing tumours which are most frequently encountered *in the cerebellum in children, where* they arise in the region of the roof of the fourth ventricle They are composed of masses of rounded undifferentiated cells (Fig 23) and show a marked tendency to become disseminated through the subarachnoid space both of the brain and of the spinal cord. This subarachnoid metastasis is not peculiar to the medulloblastoma but apparently may occur in the case of any of the gliomas. The medulloblastoma is one of the more malignant gliomas, and the average duration of illness is six months before and six months after operation. Radiation appears to be of considerable value in retarding the growth of this tumour.

2. *Spongioblastoma Multiforme.* This is an extremely malignant glioma arising in middle life and almost invariably found in the cerebral hemispheres. It tends to infiltrate the brain extensively and often attains an enormous size. It is a reddish, highly vascular

tumour, and often exhibits haemorrhages and areas of necrosis (Fig 24). Microscopically it consists of relatively undifferentiated round or oval cells, together with spongioblastic and astroblastic forms. No form of treatment prolongs life for more than a few months,

FIG 24 Spongioblastoma multiforme. Note haemorrhage areas and displacement of ventricular system.

and the average survival period for those surgically treated is twelve months

3. *Astrocytoma* These are white, infiltrating growths which may occur at any age and in either the cerebral or the cerebellar hemispheres. They are slowly growing and relatively benign, and the average survival period after the first symptom is sixty-seven months in the case of the former and eighty-nine months in the case of the latter. The cerebellar astrocytoma of childhood is a particularly benign tumour Microscopically (Fig. 25) they exhibit abundant astrocytes and, in the case of the fibrillary astrocytomas, a dense fibril network, and the tumour cells exhibit attachments to the blood-vessels characteristic of the astrocyte. Astrocytomas are particularly liable

to undergo cystic transformation. Gliomatous cysts, therefore, have on the whole a favourable prognosis, though cystic change is fairly common in the spongioblastomas.

4. *Oligodendroglioma.* This is a rare, slowly growing, relatively benign tumour occurring in the cerebral hemispheres in young adults. The cells of which it is composed exhibit features which are held to relate them to oligodendroglia
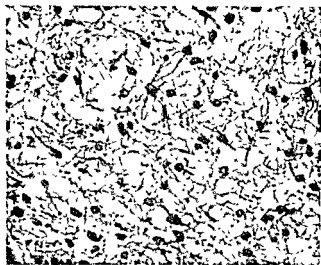

Fig 25 Astrocytoma

5. *Ependymoma.* This is a firm, whitish tumour, sometimes papilliferous, arising from the ependyma, frequently in the roof of the fourth ventricle and sometimes from the walls of the other ventricles and from the central canal of the spinal cord

6. *Ganglioglioma.* This rare tumour is composed of ganglion cells surrounded by glioma tissue composed of astrocytes and astroblasts

7. *Neuroblastomas* and *Ganglioneuromas,* though not glial in origin, may conveniently be mentioned here. Both are rare tumours, the former consisting of neuroblasts and the latter of ganglion cells and in some instances of nerve-fibres, which are usually unmyelinated.

Meningioma.

These tumours were at one time thought to arise from the dura mater and hence were known as dural endotheliomas. It is now believed, however, that although they are attached to the dura many arise from the arachnoid cells which penetrate the dura to form the arachnoid villi, projecting into the dural venous sinuses. They

are composed of specialized connective-tissue cells resembling the cells which constitute the arachnoid villus. These cells are present in columns or whorls (Fig. 26), and the tumour sometimes contains fibroglia together with collagen fibres and small calcified concretions known as psammoma bodies. They have therefore been termed 'meningeal fibroblastoma' and 'arachnoid fibroblastoma'. The
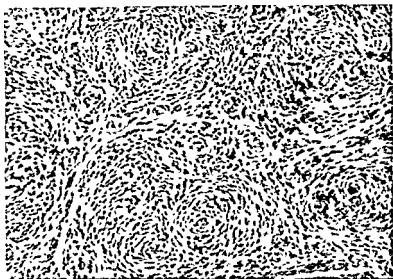

Fig. 26. Meningioma. H. E. × 133.

term 'meningioma', however, though less completely descriptive, is more convenient.

Commonly the meningioma is a single large, more or less irregularly lobulated growth, but less frequently it may form a flat plaque spreading over the inner surface of the dura. A distinctive feature of the meningiomas is their relationship to the bones of the skull. Though hyperostosis may be the reaction of the bone without its having been invaded, these tumours tend to invade the overlying bone in about 20 per cent. of cases, absorption of bone and new bone formation occurring simultaneously. In this process the outer table of the skull may be absorbed and rebuilt so as to constitute a bony boss (Fig. 36, p. 246). Microscopically meningioma cells fill the Haversian canals and spaces. New bone is laid down in spicules perpendicular to the surface of the skull, the osteogenetic cells being derived from the outer layers of the dura or from the bone itself. In rare cases a meningioma may perforate the skull and infil-

trate the extracranial tissues. The meningioma, which is of meso-dermal origin, does not invade the brain but compresses it, and the resulting disturbance of cerebral function is as a rule much less marked in proportion to the size of the tumour than is the case with the gliomas.

Since the meningiomas arise from the cells of the arachnoid villi they are commonly found along the course of the intracranial venous sinuses, and their sites of greatest predilection are the superior longitudinal sinus—parasagittal meningiomas, the sphenoparietal sinus and the middle meningeal vessels—meningiomas of the convexities; the olfactory groove of the ethmoid; and the circle of sinuses around the sella turcica—suprasellar meningiomas Meningiomas are very rare below the tentorium. Multiple meningiomas may occur in association with multiple neurofibromas (see p 562).

Auditory Nerve Tumour.

Auditory nerve tumours are usually unilateral. Rarely they are bilateral and are then usually, *though not always*, manifestations of generalized neurofibromatosis and may be associated with multiple meningiomas (see p. 562). Familial examples of bilateral auditory nerve tumour have been reported. Penfield believes that the solitary auditory nerve tumour can be differentiated histologically from that associated with generalized neurofibromatosis A solitary tumour consists of elongated cells like spindle fibroblasts with much collagen and reticulum, and exhibits marked palisading and parallelism of nuclei. Mallory and Penfield believe that these tumours arise from the perineurial or endoneurial connective tissue and that the fibroblast is their type cell. Mallory therefore terms them 'perineurial fibroblastomas'. Though the eighth cranial nerve is their commonest site, similar tumours may be found upon other cranial nerves, especially the optic and the trigeminal, upon spinal nerve-roots, usually the posterior, and upon peripheral nerves. The neurofibroma of von Recklinghausen is thought by Penfield to differ from the tumour just described in that nerve-fibres are found within it. For clinical purposes the term 'acoustic neuroma' may conveniently be used to include both types of tumour if indeed they are histologically distinct.

Blood-vessel Tumours.

The blood-vessel tumours of the brain have only been subjected to detailed study comparatively recently and any classification is necessarily to some extent provisional. The following forms are encountered:

(1) The angiomatous malformations, including the cirsoid aneurysms.

(2) The cavernous haemangiomas, and

(3) The angioblastomas.

1. *The Angiomatous Malformations*. These are probably to be regarded as congenital abnormalities of vascular development rather than as true neoplasms. They are divided into (i) telangiectases, (ii) angioma venosum, and (iii) angioma arteriale.

(i) *Telangiectases*, or capillary angiomas, consist of groups of greatly dilated capillaries. They may be associated with Osler's hereditary telangiectasia and are usually accidental post-mortem findings, though rupture has been known to cause death.

(ii) *Angioma Venosum*. The venous angiomas consist of masses of dilated leptomeningeal and perforate cerebral veins, which do not pulsate when exposed at operation. Occasionally they arise in the dura or in association with the dural venous sinuses. Histologically degeneration of cerebral tissue with gliosis is observed between the vessels. Three varieties have been described: (a) simple varix, (b) serpentine varix, (c) the racemose or cirsoid type. Congenital naevi — port wine marks — on the face, tortuosity of the retinal vessels, and in some cases unilateral buphthalmos may be associated with venous angioma of the cortex on the same side (Sturge-Weber syndrome).

(iii) *Angioma Arteriale*. This vascular abnormality consists of a mass of enlarged cortical veins in direct communication with an artery, which is often abnormally large. The vessels, which pulsate, contain arterial blood. Both veins and arterial angiomas are most frequently encountered in the field of the middle cerebral artery. Facial naevus does not appear to have been observed in association with arterial angioma, but increased extracranial vascularity is frequently present. Increased vascularity of the scalp, with large and pulsating arteries, and hypertrophy of one or both carotids may be present, and even secondary cardiac hypertrophy may occur.

2. *The Cavernous Haemangiomas*. The cavernous haemangiomas appear to be congenital abnormalities rather than true neoplasms. They usually occur above the tentorium. They form a lobulated mass consisting of small and large spaces containing blood. They are situated in the white matter of the hemispheres or in the basal ganglia and have no connexion with the meninges. Microscopically they consist of cavernous and capillary spaces, the walls of which are composed of collagen lined with a single layer of endothelial cells. Exceptionally a cavernous haemangioma may be associated with abnormalities elsewhere in the body, for example, cysts in the suprarenal and kidney and subcutaneous haemangiomas. (D. S. Russell)

3. *The Angioblastomas*. The angioblastomas are tumours which,

according to Cushing and Bailey, are composed of angioblasts, the primitive cells which normally form the foetal blood-vessels. They usually consist of vascular channels and spaces with sparse intercapillary tissue containing swollen fat-laden endothelial cells They exhibit a marked tendency to form cysts in the surrounding nerve-tissue, the cyst containing xanthochromic fluid which is probably an exudate from the vessels of the tumour. The cyst may be large and the tumour a small nodule in its wall, which must be excised if the cyst is not to refill. The angioblastomas are almost invariably subtentorial tumours, though two examples have been observed above the tentorium (Barnard and Rochat). They are usually single, but there may be multiple growths in the cerebellum or in addition to a cerebellar tumour a tumour in the medulla or spinal cord An important feature of the angioblastomas is their frequent association with abnormalities in other parts of the body. The most important of these, because the most easily observed, is an angioblastoma of the retina (von Hippel's disease). This is a small tumour usually situated in the periphery of the retina and supplied by an enlarged artery and vein. Secondary proliferative changes in, and rarely even detachment of, the retina may render it difficult to recognize Other abnormalities which may co-exist are cysts of the pancreas and kidneys and hypernephromas of the kidneys or the suprarenal glands. The coincidence of these abnormalities is known as Lindau's disease and is familial in about 20 per cent of cases

Hypophyseal Epidermoid Tumours.

These tumours are also described as tumours of the craniopharyngeal, or Rathke's, pouch and adamantinomas. In order to understand their origin it is necessary briefly to review the development of the pituitary gland in the embryo.

The pituitary develops as a result of fusion of an evagination of the ectoderm of the stomodaeum with a process which extends downwards from the floor of the forebrain. The former loses its opening into the mouth cavity and becomes a closed sac from which are derived the pars anterior and the pars intermedia of the pituitary. The process from the forebrain forms the pars posterior and the infundibulum. The remnants of the cranio-pharyngeal pouch remain, and, owing to rotation of the developing gland, come to lie anterior to the infundibulum and at the upper angle of the pars anterior. They may also be found within the sella turcica itself.

Tumours arising from these embryonic relics show characteristics resulting from their origin in the stomodaeum. They contain cells resembling those of the buccal epithelium of the embryo, including the ameloblasts of the embryonic enamel organ. These tumours

are very liable to undergo cystic degeneration and calcification and may even develop bone. They usually arise above the sellar diaphragm, but occasionally within the sella itself.

Pituitary Tumours.

The common pituitary tumours are adenomas. The commonest of these is the chromophobe adenoma, composed of cells which sometimes show alveolar formation and resemble the chromophobe cells of the normal gland, so-called on account of the absence of acidophil and basophil granules in their cytoplasm. The endocrine disturbances associated with chromophobe tumour are those of 'hypopituitarism'. The chromophil adenoma is composed of cells resembling the acidophil cells of the normal gland. It sometimes undergoes cystic degeneration, and gives rise to symptoms of hyperpituitarism—gigantism and acromegaly. The basophil adenoma is microscopic in size and does not give rise to pressure symptoms.

The pituitary adenomas arise within the sella turcica, which they expand, and later may pass through the sellar diaphragm and attain a considerable size, compressing the structures at the base of the brain

Adenocarcinoma of the pituitary is a rare, rapidly growing tumour which gives rise to metastases.

The occurrence within the sella turcica of metastases from extracranial tumours is rare and has been most frequently recorded in cases of carcinoma of the breast.

Cholesteatoma.

The cholesteatoma, or cerebro-spinal epidermoid, is a rare tumour of adult life which affects males more frequently than females. It is regarded as a foetal epithelial inclusion and is most frequently found in the subarachnoid cisterns at the base of the brain. Those arising below the tentorium, a common site, may be situated either in the cerebello-pontine angle or in the middle line on the ventral aspect of the cerebellum and within the fourth ventricle or in the temporal bone The naked-eye appearance of the tumour in the fresh state is highly characteristic. It is pearly white, smooth, and glistening, firm but brittle. Microscopically a cholesteatoma is composed of several layers, of which the most characteristic—the stratum granulosum—consisting of several rows of large, finely granular cells, probably corresponds to the dermis.

Pinealoma.

Tumours of the pineal gland are rare. The commonest form contains two types of cell, a large cell with a clear cytoplasm and smaller

cells resembling small lymphocytes. Glial cells may also be present in the tumour. Teratomas sometimes originate in the pineal body. Greenfield has reported a pineal tumour in which in addition to the two types of cell just described epithelial cells and keratin were present.

Colloid Cysts of the Third Ventricle.

These are rounded cystic tumours measuring from 1 to 3 cm. in diameter and arising from the choroid plexus They are lined with ciliated epithelium and contain thick glairy fluid or gelatinous material. Owing to their position they readily cause hydrocephalus. Papilloma of the choroid plexus may also occur.

Rare Forms of Intracranial Tumour are chordomas; osteomas, arising from the inner table of the skull, primary sarcomas, especially chondro-myxosarcomas, and intracranial dermoids

Chordomas are tumours derived from remnants of the notochord. Within the skull they are found in the region of the spheno-occipital synchondrosis.

Metastatic Tumours.

About one in twenty cerebral neoplasms is secondary to a primary growth elsewhere, usually in the lung, breast, stomach, prostate, or pancreas The lung appears to be the commonest source of metastatic cerebral tumour and not infrequently the symptoms of the cerebral growth are more conspicuous than those of the primary Secondary cerebral carcinomas are usually multiple and rapidly growing. Hence the history of symptoms is usually short. They are pinkish, rounded tumours, well defined from the surrounding brain tissue. An important variety of secondary carcinoma within the skull is constituted by a group of cases in which the tumour cells infiltrate the dura at the base of the skull and spread into the leptomeninges and the bones of the base. This condition is sometimes described as carcinomatosis of the meninges and may lead to subdural haematoma. Many of the cranial nerves are often compressed or infiltrated. The pituitary gland may be invaded and the tuber cinereum compressed, leading to metabolic and endocrine disorders. In such cases metastatic deposits may be present in the uppermost cervical lymph nodes. Secondary sarcoma of the brain is much rarer than secondary carcinoma.

Tumours of Infective Origin.

Tuberculoma.

Tuberculoma of the brain appears to be much less frequent than a generation ago, when it was regarded as one of the commonest of

intracranial tumours. Cerebral tuberculomas are more frequently subtentorial than supratentorial and vary in size from small nodules up to large masses which may occupy more than one lobe of the brain. They are usually at some point subjacent to the pia mater. There is a yellow caseous centre surrounded by a pinkish grey outer zone Microscopically cerebral tuberculomas show the features characteristic of tuberculous lesions elsewhere. The caseous centre is surrounded by a zone containing giant cells and epithelioid cells and vessels showing endarteritis. Outside this area infiltration with compound granular corpuscles and fibrosis is conspicuous.

Gumma

Gumma of the brain is extremely rare. It is generally connected with the meninges, probably arising as a circumscribed patch of gummatous meningitis. Its pathology is described in the section on cerebral syphilis.

Parasitic Cysts

Intracranial hydatid cysts are rare even in countries in which hydatid infection is common, the brain being infected in only 5 per cent. of cases (Brailsford). They may be single or multiple. They sometimes occur outside the dura, and in one patient whom I saw an extradural collection of hydatids eroded the frontal bone and some cysts were extruded through the scalp. More often the cysts, which frequently attain the size of a hen's egg, occupy the substance of the cerebral hemispheres or lie within the ventricles. Cysticercus cellulosae occurs more frequently within the skull than the hydatid cyst. Cysticerci are usually multiple and may be present in very large numbers. The cysts, which are generally about the size of a pea, are frequently found in the subarachnoid space, and the cerebral cortex may be studded with them. They may also occur in the region of the basal ganglia and within the ventricles. It is stated that sudden death may be caused by a cysticercus within the fourth ventricle. Both types of parasitic cyst may be found in other parts of the body, where their presence affords confirmation of the nature of the intracranial lesion. Hydatids are likely to be found in the liver, lungs, peritoneal cavity, or bones. Cysticerci may be present in the subcutaneous tissues or muscles, as rather hard, oval bodies, about the size of a pea. Rarely infection of the brain with the ova of Schistosoma Japonicum may cause tumour-like masses.

PATHOLOGICAL PHYSIOLOGY

The functions of the brain depend upon the maintenance of the circulation of the blood and of the cerebro-spinal fluid at their

appropriate pressures. The brain is unique among the viscera in being confined within a rigid box, the cranium. It follows that the total volume of the intracranial contents, the brain and its coverings, the blood-vessels and the blood, and the cerebro-spinal fluid is constant, and that an increase in the volume of any one of them can only occur at the expense of the others. The intracranial contents, however, do not respond passively to changes in their volume or pressure, but react in complicated ways, so that any such alteration has far-reaching consequences. Four factors which influence the intracranial pressure require consideration—the mass of the brain, the circulatory system, the cerebro-spinal fluid, and the rigidity of the skull.

The Mass of the Brain.

An intracranial tumour usually increases the mass of the brain, though in the case of certain slowly growing infiltrating tumours the increase in mass may be very slight, with the result that symptoms of increased intracranial pressure are slight or absent The direct local effects of the increased mass of the brain produced by a tumour play a comparatively small part in raising intracranial pressure. Owing to the partial division of the cranial cavity into compartments by the falx and the tentorium, the local rise of pressure is to a considerable extent limited to the cranial compartment in which the tumour arises and is exerted upon the overlying area of skull and dura mater and neighbouring dural processes, such as the falx and tentorium.

The Cerebral Circulation.

Disturbance of the cerebral circulation produced by an intracranial tumour contributes both directly and indirectly to the rise of intracranial pressure. The vascular channels first compressed are naturally those in which the blood-pressure is lowest, namely, the veins and venous sinuses. Compression of veins in the neighbourhood of a tumour causes oedema of surrounding nervous tissue and so adds to the local rise of pressure. It also causes a diversion of the venous blood-stream into other channels, and this leads indirectly to a general rise in intracranial venous pressure. This tends to increase the formation and impede the absorption of cerebro-spinal fluid

The Cerebro-spinal Fluid.

Besides causing increase in the pressure of cerebro-spinal fluid through the disturbance of the cerebral circulation just described, a tumour may lead to *hydrocephalus by obstructing the circulation* of the fluid, as described in the section on hydrocephalus.

The Rigidity of the Skull.

In the adult after union of the cranial sutures the skull is rigid and unyielding, and by preserving the volume of the intracranial contents constant is responsible for the far-reaching effects of a disturbance of the intracranial pressure. In the child the non-union of the sutures provides a partial safety-valve and allows of some expansion Hence a marked rise of intracranial pressure in childhood leads to separation of the sutures, and the skull yields a cracked-pot sound' on percussion. Some relief of the pressure results and other signs of raised intracranial pressure are often slighter in childhood than in later life.

MODE OF ONSET

The rate of onset of symptoms depends upon the nature of the tumour and is slowest in the case of astrocytomas and meningiomas, and most rapid in the most malignant gliomas and in secondary carcinoma In the first two, epilepsy may precede other symptoms by many years: in the last two either progressive focal symptoms or symptoms of increasing intracranial pressure, or both, develop in a few months. Rarely the onset is apoplectiform.

GENERAL SYMPTOMS

The symptoms of an intracranial tumour are conveniently divided into general symptoms attributable to increased intracranial pressure, and focal symptoms which are due to the local effects of the growth. It might be expected that focal symptoms would arise before a tumour was large enough to disturb the intracranial pressure   More frequently, however, the reverse is the case, and the general symptoms often indicate the presence of a tumour which it is by no means easy to localize. Headache, papilloedema, and vomiting may be described as the classical triad of symptoms of increased intracranial pressure, but they are not found with equal frequency. In one series headache was present in 88 per cent., papilloedema in 75 per cent , and vomiting in 65 per cent. of cases of cerebral tumour. All three were found together in only 60 per cent. It is clearly unnecessary that all, or indeed any, of these symptoms should be present in order to diagnose an intracranial tumour.

Headache. The headache of intracranial tumour is probably mainly due to abnormal states of tension in the cerebral blood-vessels (Northfield, 1938). It is paroxysmal, at least in the earlier stages. It is often described as a throbbing or a 'bursting' pain. It occurs chiefly during the night and in the early morning. Often the patient awakens with a headache which lasts from a few minutes

to a few hours and then passes off, to recur the next day. With the gradual enlargement of the growth the headaches tend to become more prolonged and may ultimately be continuous. They always tend to be intensified by any activities which raise the intracranial pressure, such as exertion, excitement, coughing, sneezing, vomiting, stooping, and straining at stool. They may be influenced by posture, *being worse when the patient is lying down, or lying upon one side,* and may be relieved by adopting a sitting attitude.

Owing to the early occurrence of a diffuse rise of intracranial pressure in many cases of cerebral tumour, headache is of little localizing significance The pain due to the local pressure of the growth may be predominantly unilateral, on the side of the tumour, and is often associated with tenderness of the skull on percussion over a limited area overlying it In the case of subtentorial tumours the headache in the early stages may be mainly suboccipital, with a tendency to radiate down the back of the neck. As the intracranial pressure rises the headache tends to be diffuse, and hydrocephalus may lead to paroxysms of severe diffuse pain radiating down the neck and sometimes associated with head retraction. Pressure upon the trigeminal nerve leads to unilateral pain, most commonly following the distribution of the first division and associated with hyperalgesia or analgesia over the same area.

Papilloedema The pathogenesis and appearances of papilloedema are described on p. 137. Its incidence varies according to the situation of the tumour. It is almost constant in tumours of the cerebellum, fourth ventricle, and temporo-sphenoidal lobe, but is absent in half the cases of pontine and subcortical tumours It is usually late in developing in the case of prefrontal tumours, and is often more severe with extracerebral than with intracerebral growths Cerebellar tumours cause papilloedema of the greatest severity, sometimes amounting to 7 or 8 dioptres of swelling. A slight difference in the degree of swelling of the two optic disks is not uncommon, but is of no value as an indication of the situation of the tumour. *A tumour arising sufficiently near the optic foramen to cut off the* subarachnoid space of the optic nerve from communication with the cerebral subarachnoid space causes primary optic atrophy without papilloedema.

The changes in the visual fields due to papilloedema consist of enlargement of the blind spot with concentric constriction at the periphery of the field. Visual acuity deteriorates, and if the condition progresses optic atrophy and complete blindness are likely to result. Patients with papilloedema are liable to brief transitory attacks of blindness which are probably due to a temporary increase in the obstruction to the venous drainage of the retina.

Vomiting. Vomiting, when due to intracranial tumour, usually occurs during the night or in the early morning when the headache is especially severe. Though sometimes, especially in children, it is preceded by little nausea, there is no ground for the belief that vomiting of cerebral origin is always of this precipitate character. The relationship of the incidence of vomiting to the site of the tumour suggests that this symptom is probably an indication of ventricular distention

Epileptiform Convulsions. Generalized epileptiform convulsions may be a symptom of increased intracranial pressure, e g. in hydrocephalus, but it is often impossible to decide whether the convulsions are due to the increased pressure, or are local effects of the cerebral tumour responsible for it.

Aphasia Mild degrees of aphasia, especially difficulty in naming objects, may be produced by increased intracranial pressure in the absence of a lesion involving the so-called 'speech centres'; for example, in cases of cerebellar tumour.

Vertigo Vertigo, when a symptom of increased intracranial pressure, is not often a subjective sense of rotation, but more frequently a feeling of unsteadiness, with a tendency to fall on stooping

Disturbances of Pulse-rate and Blood-pressure. An acute or sub-acute rise of intracranial pressure, such as that due to intracranial haemorrhage or meningitis, often causes slowing of the pulse-rate, usually to between 50 and 60 beats a minute. If the pressure continues to increase the pulse becomes extremely rapid. In either case it may be irregular. A gradual increase in the intracranial pressure, such as that due to an intracranial tumour, does not usually cause bradycardia, but moderate tachycardia is not uncommonly found in cases of subtentorial tumour.

A rapid rise of intracranial pressure usually causes a rise of blood-pressure Thus in intracranial haemorrhage a progressive rise of blood-pressure probably indicates that the bleeding is continuing. Chronic rise of intracranial pressure does not have this effect, and in patients with intracranial tumour, especially when the lesion is below the tentorium, the blood-pressure is often subnormal.

Respiratory Rate. A gradual rise of intracranial pressure does not at first affect the respiratory rate A rise of sufficient rapidity and severity to produce loss of consciousness usually leads at first to slow and deep respirations. Later the respiratory rate may become irregular, e g of the Cheyne-Stokes type, in which periods of apnoea alternate with a series of respirations which wax and wane in amplitude In the terminal stage of a fatal increase of intracranial pressure the respirations are rapid and shallow.

'*Hypopituitarism.*' Any state of increased intracranial pressure associated with internal hydrocephalus may lead to symptoms of 'hypopituitarism', namely adiposity and genital atrophy. This is due to downward pressure of the floor of the distended third ventricle, which may erode the clinoid processes and diaphragma sellae and compress the pituitary gland. These symptoms commonly arise in children and are most frequently seen in cases of cerebellar tumour. It is not easy to say whether they should be ascribed to compression of the hypothalamus or of the pituitary gland itself. Possibly both are in part responsible.

Radiography of the skull in such cases shows erosion of the clinoid processes and slight general enlargement of the sella turcica. This group of symptoms, if misinterpreted, may lead to the erroneous diagnosis of a pituitary or suprasellar tumour.

Somnolence. Persistent somnolence is seen when hydrocephalus is pronounced and with tumours near the hypothalamus. Narcolepsy is uncommon.

Glycosuria. Glycosuria is occasionally encountered, sometimes with hyperglycaemia, more often with a normal blood-sugar and a lowered renal threshold. ,

Mental Symptoms The most varied mental symptoms may be associated with increased intracranial pressure. If the pressure rises sufficiently high all mental activity is suspended in coma, and the more rapid the rise the more likely is this to occur. An acute or subacute rise of pressure insufficient to produce coma usually leads to mental confusion with disorientation in space and time. Chronic rise of intracranial pressure may lead to progressive dementia, with a failure of intellectual capacity, emotional apathy, carelessness with regard to the person, and incontinence of the sphincters. Or the mental state may rather be one of confusion, with disorientation and hallucinations. Less frequently, marked disturbances of emotional mood are conspicuous, and the patient suffers from outbreaks of excitement in which he may be violent, or from depression in which he may be suicidal. In the mildest cases some impairment of memory and of power to concentrate, with irritability, may be the only mental symptoms.

In cases of intracranial tumour mental symptoms are most likely to occur when the tumour is situated in the frontal lobe or corpus callosum or leads to a considerable degree of aphasia, but they may be produced by a tumour in any situation which causes a rise of intracranial pressure. Thus any of the mental disturbances described may be produced by a tumour of the cerebellum. Mental symptoms as a result of increased intracranial pressure are more likely to occur in the middle-aged and elderly than in younger patients.

False Localizing Signs.

Collier drew attention to the importance of symptoms, especially cranial nerve palsies, produced by intracranial tumours in other ways than by direct compression. Since these, unless properly interpreted, may lead to mistakes in localization, he termed them 'false localizing signs' A sixth-nerve palsy on one or both sides, and, less frequently, a third-nerve palsy, may be thus produced and have been variously attributed to stretching of the nerves, to their compression by arteries, and to other modes of interference with their function resulting from displacement of the cranial contents. Other false localizing signs include bilateral extensor plantar responses or bilateral grasp reflexes resulting from interference with the function of the cerebral hemispheres by distension of the ventricles in hydrocephalus; 'hypopituitarism' resulting from hydrocephalus, as already described; an extensor plantar response occurring on the same side as a tumour of one cerebral hemisphere produced by compression of the opposite cerebral peduncle against the tentorium; cerebellar symptoms resulting from tumours of the frontal lobe, and midbrain symptoms, especially fixed dilated pupils, produced by a tumour of the cerebellar vermis.

Examination of the Head.

Examination of the head may yield important information in cases of intracranial tumour and should never be neglected. There may be visible enlargement when hydrocephalus develops before the union of the cranial sutures. In such cases separation of the sutures may yield a 'cracked-pot sound' on percussion. Local tenderness of the skull may be present in the region overlying the tumour. A bony boss may overlie a meningioma (Fig. 36). Venous congestion of the scalp is a not uncommon result of increased intracranial pressure and is most evident in children. When there is a marked rise of intracranial pressure with separation of the sutures, extreme venous congestion of the scalp occasionally occurs. Congestion and tortuosity of the arteries of the scalp are sometimes associated with a vascular intracranial tumour, especially a meningioma or an angioma. Such arterial congestion is usually confined to the side of the tumour and is often most evident in the superficial temporal artery. An audible bruit should be sought by auscultation. It is most frequently present over an arterial angioma, much less frequently over a highly vascularized meningioma, very rarely in the presence of an aneurysm.

Facial naevus may be associated with venous angioma, retinal angioblastoma with angioblastoma of the cerebellum, and cutaneous pigmentation with neurofibromatosis.

Attention should be paid to the presence or absence of exophthalmos.

Accessory Methods of Investigation.

Radiography

Not many years ago it was believed that radiography of the skull could throw little light upon the localization of an intracranial tumour. Now, however, it is recognized to be an indispensable method of investigation, and in every suspected case stereoscopic
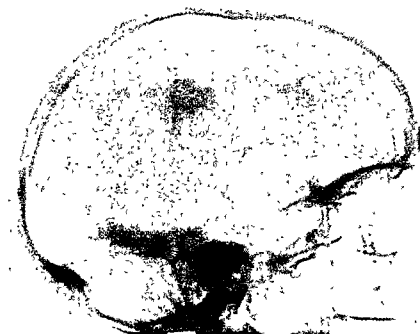

Fig. 27. Cystic hypophyseal epidermoid tumour filled with air after eroding sella turcica and rupture into sphenoidal sinus.

lateral, antero-posterior, and postero-anterior views should be taken, and other positions may be valuable. Radiographic examination of the skull may reveal abnormalities in the bones, calcification in the tumour, or displacement of the pineal body. In selected cases further radiograms may be taken after the injection of air into the cerebral ventricles, ventriculography, or into the spinal subarachnoid space, encephalography. The commonest abnormality observed in the bones of the skull is a general erosion or 'convolutional thinning' (Fig. 26). The radiograms show many rounded areas of rarefaction, sometimes described as 'finger-printing' or a 'beaten silver' appearance. The rarefied areas are produced by the pressure of the summits of the gyri. Convolutional thinning is an indication

of a considerable generalized rise of intracranial pressure. A somewhat similar appearance is normal in children and may persist up to the twenty-fifth year. Separation of the sutures may be seen when a rise of intracranial pressure occurs before the age at which these unite. It is most commonly seen in childhood. Local erosion of the bone is most frequently seen in the region of the skull superficial to
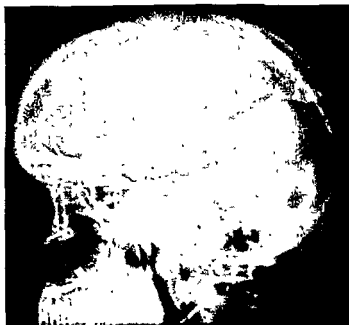
FIG. 28. Arterial angioma in parieto-occipital region. Note the calcification in the tumour and the enlarged vascular channels.

a meningioma. Around the eroded area new bone formation occurs, often taking the form of spicules, perpendicular to the vault, and surrounding this there is frequently a network of deepened vascular channels in the bone. The petrous portion of the temporal bone may be eroded by an acoustic neuroma which may lead to unilateral enlargement of the internal auditory meatus. Bony changes in the region of the sella turcica are produced not only by tumours of the pituitary gland itself and those arising in its neighbourhood, but also by a general increase in the intracranial pressure. Pituitary tumours cause a uniform expansion of the sella turcica with thinning of its walls. The ballooned sella projects downwards and forwards into the sphenoidal sinuses, and the upward pressure of the growth

may erode the clinoid processes. Tumours arising outside the sella, but immediately above it, cause erosion of the clinoid processes and flattening of the sella, which is not, however, uniformly enlarged unless invaded by the tumour (Fig. 27), while the downward pressure of the floor of the distended third ventricle in internal hydrocephalus results in a very similar radiographic appearance.

Fig. 29. Extensive calcification in an oligodendroglioma situated in the left temporo-parietal region. The convolutional markings due to increased intracranial pressure and the enlargement of the pituitary fossa are well seen. (Radiogram by Dr. Jupe.)

Calcification is most frequently observed in cysts of the craniopharyngeal pouch, in which it is visible as a radiographic opacity in 75 per cent. of cases. These tumours may exhibit on the X-ray film merely a few opaque flecks, or a mass the size of a hen's egg.

Calcification is common also in the angiomas, which may present a characteristic convoluted appearance due to the deposit of calcium in the walls of the vessels composing the tumour (Fig. 28). Meningiomas also sometimes show calcified areas, and these may be encountered, though less frequently, in gliomas (Fig. 29), teratomas, tumours of the choroid plexuses, and tuberculomas.

that cerebral exploration can be performed without delay if it should become necessary.

Encephalography.

The injection of air into the lumbar subarachnoid space is a much simpler procedure than its introduction directly into the ventricles,
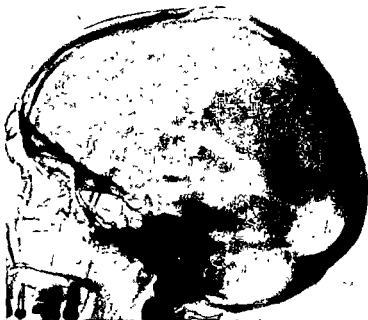
FIG 31. The left lateral ventricle is depressed and encroached on by a left parietal tumour (glioblastoma). (Radiogram by Dr. Jupe.)

and by this means air may be induced to enter not only the cerebral ventricles but also the cerebral subarachnoid space. Radiography after the lumbar injection of air is known as encephalography. It is more liable to cause headache than ventriculography, and it is contra-indicated when the intracranial pressure is very high and in all cases when a subtentorial tumour is suspected, on account of the risk of herniation of the medulla into the foramen magnum. It is indicated as a substitute for ventriculography in suspected cases of tumour or atrophy of the cerebral hemispheres and in other conditions when it is desired to demonstrate the patency of the foramina of Luschka, or the presence of abnormalities in the cerebral sub-arachnoid space.

The patient should be given a preliminary injection of morphine, gr. 1/6th, and scopolamine, gr. 1/200th or a general anaesthetic. Lumbar puncture is performed in the usual way with the patient seated in an upright position. A two-way needle, to which a mano-meter can be attached, should be used. Ten c.c. of spinal fluid
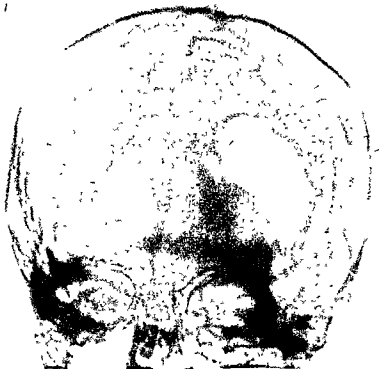
FIG. 32. Large basal ganglia tumour rising from the floor of the right ventricle and partly filling its lumen. The whole ventricular system is displaced away from the side of the lesion. (Radiogram by Dr Jupe.)

are withdrawn and replaced by the injection of air. A further quantity of fluid is then withdrawn and more air is injected, the pressure being maintained at about 150 c.c. of fluid. During the injection the head is held with the neck slightly flexed when it is desired to fill the ventricles and extended when it is desired to fill the subarachnoid space. It is usually possible to introduce about 100 c.c. of air, and radiograms are taken and interpreted as after ventriculography (Fig. 34).

Indications for Ventriculography and Encephalography. Neither of these procedures is devoid of risk, and fatalities have been reported.

Fig 33. Frontal glioma causing a filling defect and slight depression of the anterior horn. (Radiogram by Dr Jupe)
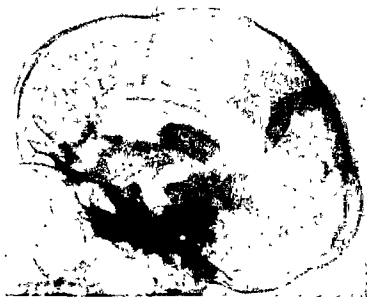
Fig 34. Normal encephalogram showing the lateral, third, and fourth ventricles. (Radiogram by Dr. Jupe)

They are only to be recommended, therefore, when neither clinical investigation nor simple radiography has rendered possible the localization of a suspected intracranial tumour. Even in such cases ventricular estimation may demonstrate that the tumour is probably subtentorial, in which case ventriculography would probably yield no further information. When a supratentorial tumour is suspected
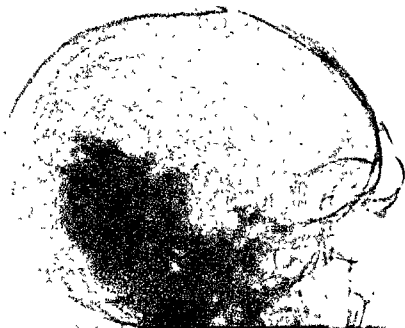
Fig. 35. Arterial angioma in parieto-occipital region: angiography with thorotrast.

and clinical data are inadequate for localization, ventricular estimation may indicate in which hemisphere the tumour is situated, but ventriculography may enable it to be localized exactly. As already mentioned, ventriculography is possible when encephalography is contra-indicated. When either is applicable, the choice is a question of convenience.

Arterial Encephalography. (Cerebral Angiography)

Moniz has devised a method of investigating radiographically the distribution of the cerebral arterial supply, radiograms being taken immediately after the injection into the common carotid artery of thorotrast, a solution opaque to X-rays. It may thus be possible to demonstrate abnormal vascularity in an aneurysm, angioma (Fig. 35),

vascular glioma, or meningioma, or the displacement of cerebral arteries by an avascular tumour. The procedure, however, is not without risk and it can only be justified in those rare cases in which localization of a tumour has proved impossible both by clinical methods and by ventriculography with air.

Electro-encephalography. '

Electro encephalography may yield localizing evidence of a tumour in the shape of a focus of large delta waves corresponding to the site of the growth (Walter, 1936–7, 1938).

The Cerebro-spinal Fluid.

Lumbar puncture should be carried out with caution in suspected cases of intracranial tumour when there is a marked rise of intracranial pressure, especially when there is reason to suspect that the tumour is in the posterior fossa. In such cases the rapid withdrawal of cerebro-spinal fluid from the lumbar subarachnoid space may cause the medulla and cerebellar tonsils to be driven downwards into the foramen magnum, forming the so-called 'cerebellar pressure cone', with possibly fatal results. There is little risk, however, if the fluid is allowed to escape extremely slowly. The pressure of the cerebro-spinal fluid should be determined in all cases by manometry, as it is frequently raised above normal and may be as high as 500 to 1,000 mm of fluid. Usually the rise of pressure of the cerebro-spinal fluid is proportional to the severity of the signs of increased intracranial pressure. The protein of the cerebro-spinal fluid may be normal but not uncommonly is above normal, though it is not usually higher than 0·1 per cent. In some cases, however, it may be considerably above this figure and highly albuminous xanthochromic fluids are occasionally observed. A great increase in the protein content of the fluid seems most likely to occur when the tumour is in the neighbourhood of the ventricular system. It is not uncommon in tumours of the corpus callosum, but has also been observed in cases of acoustic neuroma. The cell content of the fluid is usually normal, but a slight mononuclear pleocytosis may be found when the tumour is closely related to the meninges. Exceptionally, tumour cells exhibiting active mitosis are found in the fluid. The glucose and chloride contents of the fluid are usually normal and there is no characteristic change in the colloidal gold curve.

Focal Symptoms

Frontal Lobe.

(i) *Prefrontal Tumours.* By prefrontal tumours are meant tumours confined to that part of the frontal lobe lying anterior to the precentral convolution. Tumours in this region are often hard to

localize. Headache as a rule occurs early, but papilloedema and vomiting usually develop late and may be absent. As we have seen, mental symptoms may occur with a tumour in any situation, even below the tentorium. There is evidence, however, that they are more likely to occur when the tumour is in the corpus callosum or frontal lobe than when it is elsewhere. Moreover, in the absence of other localizing signs the development of mental symptoms before signs of increased intracranial pressure favours a frontal localization The mental disturbance is a progressive dementia, of which the characteristic feature is a defective grasp of situations as a whole, a failure of the synthetic function of thought. In more severe cases the patient's intellectual capacity suffers more seriously. He becomes stupid, fails to appreciate the gravity of his illness, is careless of his dress and appearance, and develops incontinence of urine and faeces without exhibiting any sense of impropriety. Such patients are sometimes jocular and facetious and repeatedly make simple jokes or puns (Witzelsucht). Irritability of temper and depression are not uncommon.

Generalized convulsions occur in about 50 per cent of cases When the tumour is situated near the base the patient may experience an aura associated with speech He may feel as if he wishes to speak but cannot do so, and may actually stammer before losing consciousness. There may be a sensation of something gripping the throat. When the tumour is situated towards the superior aspect of the lobe the motor element in the convulsion is likely to consist of turning of the head and eyes to the opposite side with complex clonic and tonic movements of the contralateral limbs.

Catatonia is a symptom which occurs more frequently with frontal lobe tumours than with tumours elsewhere. The patient tends to become immobilized for some time in one attitude; or may maintain indefinitely an attitude into which his limbs have been manipulated by the observer—waxy flexibility.

Aphasia, of the verbal type, may occur when the tumour involves the posterior part of the inferior frontal convolution.

The grasp reflex is an important sign, when present, as it is probably pathognomonic of a frontal lobe lesion. It is most frequently observed in the hand, but may be found in the foot only when the tumour is situated in the superior part of the lobe.

A rare sign of a lesion of the frontal lobe which must not be confused with the grasp reflex is tonic innervation or perseveration, which consists of a persistence of muscular contraction voluntarily initiated, due to a failure of relaxation. Tonic perseveration is usually most evident after flexion of the fingers, but may occur after movements of other parts of the body on the side opposite to the

lesion. Muscular relaxation is slow and may not be complete for several seconds.

Pressure upon neighbouring pyramidal fibres may lead to weakness upon the opposite side of the body, usually most marked in the

Fig. 36. Erosion of bone and new bone formation leading to a bony boss overlying a left frontal meningioma.

face and tongue, and tremor may be present in the limbs either of the same or of the opposite side.

Pressure upon the olfactory nerve, lying upon the floor of the *anterior fossa, may lead to anosmia on the side of the lesion. This* is most likely to occur in the case of meningiomas arising from the olfactory groove (Fig. 36). Such tumours extending backwards may compress the optic nerve, causing primary optic atrophy on the side of the lesion, while the rise of intracranial pressure causes papilloedema on the opposite side. Cerebellar symptoms may occur and constitute a false localizing sign.

(11) *Precentral Tumours.* Precentral tumours are perhaps the

easiest to localize on account of the early development of symptoms of excitation and destruction of the pyramidal fibres.

Pyramidal excitation finds expression in a focal convulsion, of which several forms are encountered. In the typical Jacksonian fit (Fig. 37) the convulsion begins with clonic movements, rarely with tonic spasm, in a limited area of the opposite side of the body, e.g. the thumb, and slowly spreads, involving other parts in the order in

Fig. 37. Jacksonian convulsion beginning in the left side of the face, due to a tumour in the lower part of the right precentral convolution

which they are represented in the precentral convolution (see p 1). When the whole of one side of the body is convulsed the opposite side may become involved, and at this stage consciousness is usually lost. Partial Jacksonian attacks may occur, in which the convulsion is limited to a small part of one side of the body, without loss of consciousness. Such a convulsion may be continuous—'epilepsia partialis continua'. Jacksonian attacks may occur at long intervals, or with great frequency, even up to several hundreds a day—serial Jacksonian epilepsy. When consciousness is not recovered between successive attacks the condition is described as Jacksonian status epilepticus.

Motor weakness is the result of the destruction of the pyramidal fibres by the tumour, and exhibits a regional distribution corresponding to the representation of parts of the body in the precentral convolution.

Owing to the large surface extent of the pyramidal cells on the cortex, even a large cortical tumour is likely to cause weakness of

only a part of the opposite side of the body, that is, a monoplegia. With inferiorly placed tumours there is weakness of the face and tongue on the opposite side, often associated with weakness of movements of the thumb, which is represented in the adjacent area. If the tumour is at a higher level the thumb may escape, though the fingers and arm are affected, while a tumour involving principally the medial aspect of the hemisphere is likely to cause a monoplegia involving only the foot or the whole lower limb. The usual reflex changes associated with a pyramidal lesion are found, and such reflex abnormalities may be limited to the paretic part.

A tumour of the falx in the region of the paracentral lobule is likely to produce weakness of both lower limbs, beginning in the feet, one being usually affected more than the other. Retention of urine may occur owing to compression of the cortical centres for the detrusor of the bladder. There may be an impairment of postural sensibility in the toes when the sensory area of the paracentral lobule is involved.

Jacksonian convulsions are usually associated with permanent weakness of the part of the body which is the focus of the fit, but after each convulsion there is often a temporary extension of this weakness to other parts (Todd's paralysis). Sensory loss is absent, unless the tumour extends to the post-central convolution.

Temporal Lobe.

The focal symptoms of temporal lobe tumours are often slight, especially when the tumour is on the right side. When the lesion is anteriorly situated and involves the uncinate gyrus there is often a very characteristic group of symptoms. This is the cortical centre for taste and smell, and the closely associated motor functions of licking, mastication, and swallowing are also represented in this region. Tumours of the uncinate gyrus may cause so-called uncinate fits which are characterized by (1) an olfactory or gustatory aura, (2) an abnormal state of consciousness, and (3) certain motor concomitants.

(1) The aura consists of an hallucination of taste or smell which is usually unpleasant though occasionally pleasant. It may be described as resembling paint, gas, acetylene, 'something burning', or even, as one patient put it, the monkey house at the Zoo. There may be abnormal sensations referred to the nasopharynx.

(2) The patient presents a dazed or dreamy appearance and usually stops what he is doing, but does not fall. He may have no recollection of the attack afterwards or he may describe peculiar disturbances of memory, for example, the 'déjà vu phenomenon', a feeling that everything that is happening has happened before, or he may in a very short time relive in detail a large part of his past life.

(3) Involuntary licking, smacking the lips, or tasting movements frequently accompany the olfactory or gustatory aura and form the motor component of the uncinate fit.

Destruction of the uncinate gyrus leads to an impairment of taste and smell on the side of the lesion, though this does not as a rule proceed to complete loss. Generalized or Jacksonian convulsions may also occur when a tumour involves the temporal lobe.

Visual field defects may be produced by tumours of the temporal lobe. They are absent in at least half of all cases, but when present are of great localizing value. The lower fibres of the optic radiation are likely to be caught in their path around the tip of the descending horn of the ventricle The characteristic defect is therefore a crossed upper quadrantic hemianopia, the loss being usually more extensive in the ipsilateral field. Visual hallucinations may occur and consist usually of figures of people or animals comprising in many cases a complex scene. These hallucinations are thus more highly organized than those due to occipital lesions, which usually consist merely of flashes of light. Although the cortical centre for hearing is situated in the posterior part of the temporal lobe, temporal tumours do not cause complete deafness in either ear, though a unilateral lesion in this situation may lead to some bilateral impairment of hearing Temporal tumours may cause auditory hallucinations, and the patient may imagine that the words which he seems to hear are addressed to him by a person who happens to be in the room. Left-sided temporal lobe tumours cause aphasia in about 50 per cent. of cases. This may consist merely in defect in naming objects. In more severe cases the patient is unable to understand spoken words and this disability may extend to written words also When speech is even more severely disordered the patient speaks jargon, his speech consisting often of a voluble outpouring of meaningless phrases and words of his own construction. Apraxia is sometimes present.

Neighbourhood symptoms include weakness of conjugate deviation of the eyes to the opposite side, signs of a pyramidal lesion on the opposite side, especially weakness of the face, and tremor either on the same or on the opposite side of the body. Myosis and slight ptosis due to compression of the ocular sympathetic may be seen in the early stages and may give place to mydriasis and other signs of third-nerve palsy. Diminution of the corneal reflex on the affected side may be the only evidence of compression of the trigeminal nerve.

Parietal Lobe.

The parietal lobe is the principal sensory area of the cerebral cortex. Sensory disturbances therefore constitute a prominent part of the symptoms of tumours of this region. The post-central convolution

is the part of the parietal lobe most concerned with sensation. Parts of the body are here represented for purposes of sensation in a manner similar to their motor representation in the precentral convolution. From below upwards we encounter in the following order the larynx and pharynx, the tongue, the buccal cavity, the face, neck, thumb, index, second, third, and fourth fingers, the hand, forearm, upper arm, shoulder, chest, abdomen, thigh, and leg. The foci of the foot and toes are situated at the superior border of the hemisphere, and on the medial aspect, in the paracentral lobule, lie the foci of the bladder, rectum, and genital organs (see p. 2).

Irritation of the post-central convolution causes sensory Jacksonian fits which consist usually of paraesthesiae, such as tingling or 'electric shocks', rarely of pain, and which begin in that part of the opposite side of the body, corresponding to the focus of excitation. The paraesthesiae then spread to other parts in the order of their representation in the convolution. Such sensory fits may occur alone, or may be followed by a similar spreading motor discharge due to the extension of the excitation to the precentral convolution, in which case the clonic convulsion often lags behind the advance of the paraesthesiae

A destructive lesion of the post-central convolution leads to sensory loss, the extent of which corresponds in distribution to the extent of the cortical lesion. The sensory loss is of the cortical type, that is, it involves the spatial and discriminative aspects of sensation, especially postural sensibility and tactile discrimination, while the crude appreciation of pain, heat, and cold is left intact. As a result of sensory loss the patient may be unable to recognize objects placed in his affected hand—so-called 'astereognosis'.

Post-central lesions lead also to hypotonia and wasting of the affected parts and to both static and kinetic ataxia. When the patient is at rest there is often a conspicuous restlessness of the affected upper limb, sometimes amounting to 'pseudo-athetosis', and he may gesticulate exaggeratedly with the affected hand. There is likely to be considerable ataxia in the finger-nose test—'sensory ataxia'.

Parietal tumours reaching deep into the white matter may lead to 'thalamic over-reaction', an exaggerated response to unpleasant stimuli on the opposite side of the body, though this is usually present to only a slight extent. Involvement of the fibres of the optic radiation causes a crossed homonymous defect of the visual fields; and since the upper fibres are the more likely to be caught, the field defect may be confined to the lower quadrant

The posterior part of the parietal lobe constitutes a 'watershed' between the three great cortical sensory areas, the optic, auditory, and somatic. A left-sided lesion of this area may therefore be

expected to cause considerable disturbance of speech on its receptive side. Lesions of the left angular gyrus usually cause 'word-blindness', with which may be associated visual agnosia—inability to recognize objects seen—and finger agnosia Lesions of the left supramarginal gyrus may cause bilateral motor apraxia.

Occipital Lobe.

Tumours of the occipital lobe are comparatively rare Headache is an early symptom, and other signs of increased intracranial pressure are usually conspicuous Epileptiform convulsions occur in a considerable proportion of cases—50 per cent. in one series. They may be preceded by a visual aura, such as flashes of light moving from one side towards the middle line, but this is not constant Such attacks may begin with turning of the eyes to the opposite side. The characteristic focal sign of an occipital tumour is a visual field defect. This may consist of a crossed homonymous hemianopia extending up to the fixation point, or of a crossed homonymous quadrantic defect, or of a crescentic loss in the periphery of the opposite half-fields. Hemianopia may have been discovered by the patient owing to his colliding with people on his blind side Extension of the tumour to the region of the angular gyrus on the left side leads to aphasia associated with a disturbance of visual recognition. This may find expression in an inability to read, alexia, or to recognize an object seen, though the same object is recognized when placed in the hand. It is often associated with nominal aphasia Neighbourhood symptoms may be present. The commonest of these are auditory hallucinations with 'word-deafness' when the posterior part of the temporal lobe is involved; impairment of taste and smell, probably due to pressure upon the hippocampal gyrus, sensory impairment of the cortical type, and slight motor weakness, both on the opposite side; and nystagmus, hypotonia, and inco-ordination on the same side, the result of pressure transmitted to the cerebellum

Corpus Callosum.

Tumours of the corpus callosum are not common but often yield a distinctive clinical picture Mental symptoms are prominent and are often the first symptoms to be noticed It is said that mental changes are more frequently observed in cases of tumour of the corpus callosum than when the tumour is situated in any other part of the brain, including the frontal lobe. Apathy, drowsiness, and defect of memory are the commonest mental disturbances, but any of the mental symptoms already described as occurring in cases of cerebral tumour may be present. The defect of memory may be so severe that a patient who has suffered from an intense headache may

in a few minutes have forgotten it completely. General convulsions may occur. The situation of the tumour in the midline extending laterally into the central white matter on both sides leads early to damage to the pyramidal tracts. This is usually asymmetrical in the early stages and it is then common to find hemiplegia on one side, while the other exhibits the reflex changes resulting from a pyramidal lesion, with little loss of power. Later, double hemiplegia may be found. Anteriorly placed tumours extending into the frontal lobes may cause a grasp reflex on one or both sides. Apraxia is present in a small proportion of cases. It may occur on the left side only, owing to interruption of fibres linking the left supramarginal gyrus with the right pyramidal tract. Tremor and choreiform movements sometimes occur and are probably due to involvement of the corpus striatum. Signs of increased intracranial pressure are often late in developing. The protein content of the cerebro-spinal fluid is likely to be high.

Centrum Semiovale.

The centrum semiovale consists mainly of pyramidal fibres converging on the internal capsule, and sensory fibres diverging from the latter to the various cortical sensory areas. Tumours in this region may cause little disturbance of the intracranial pressure, but they usually cause motor or sensory symptoms early. Owing to the concentration of fibres near the internal capsule the whole of the opposite side of the body is likely to be affected. Anteriorly placed tumours cause a progressive spastic hemiplegia. When the tumour is situated more posteriorly the presenting symptoms are sensory, and all forms of sensibility are usually impaired on the opposite side, and sensory ataxia is present. Hemianopia may be added if the optic radiation is involved. Somnolence is not uncommon when the tumour invades the region of the optic thalamus; and signs of pressure upon the upper part of the midbrain may be found, especially weakness of conjugate deviation upwards and inequality of the pupils. The invasion of the third ventricle by the tumour is rapidly followed by the development of signs of increased intracranial pressure if these have not been present before.

Third Ventricle.

The third ventricle may be the primary site of a tumour, e.g. a colloid cyst, or it may be invaded by a tumour arising below, in the interpeduncular space, above, in the falx or corpus callosum, or laterally, in the centrum semiovale. Such extraventricular tumours usually yield ample evidence of their presence before they invade

the ventricle. Tumours arising in the ventricle, however, are often difficult to localize. Hydrocephalus may be acute, subacute, intermittent, or chronic. Severe paroxysmal headaches are common, and with papilloedema may be the only symptoms. Progressive dementia may occur, or coma may suddenly develop.

Somnolence, polyuria, hyperglycaemia and glycosuria, adiposity, sexual regression, and irregular pyrexia may be produced by downward pressure by a tumour upon the tuber cinereum and pituitary body. Lateral extension of the growth in the region of the internal capsule causes signs of pyramidal defect on one or both sides

Midbrain.

Tumours arising in the midbrain usually cause internal hydrocephalus early owing to obstruction of the aqueduct of Sylvius. Headache, papilloedema, and vomiting are therefore conspicuous Owing to the concentration in this region of the nuclei of the third and fourth cranial nerves and the supranuclear paths converging upon them, ocular abnormalities are prominent. Lesions of the upper part of the midbrain usually cause a paresis of conjugate ocular deviation upwards, and retraction of the upper lids may be associated with this. Lesions of the lower half cause paresis of conjugate ocular deviation downwards with which ptosis and paresis of convergence may be combined Conjugate lateral movement of the eyes usually escapes, at least in the early stages, from a lesion just above the pons may involve the supranuclear fibres for lateral movement at their decussation and so cause a bilateral paralysis of lateral conjugate gaze.

The pupils are often unequal and tend to be dilated. The reactions both to light and on convergence-accommodation may be lost, or the latter may be preserved when the former is lost. Asymmetrical nuclear ophthalmoplegia may occur.

The pyramidal tracts are usually involved on both sides, though one is often more severely affected than the other. The characteristic reflex changes of pyramidal lesions are present. Weakness and spasticity, slight in the early stages, progress until in some cases a condition of virtual decerebrate rigidity supervenes. 'Tonic' fits characterized by opisthotonos with extension of all four limbs and loss of consciousness may occur Tremor is common, and nystagmus and ataxia result from injury to the cerebellar connexions. Choreiform movements are occasionally observed.

Sensory changes are due to damage to the long ascending sensory paths Extensive areas of analgesia and defect of postural sensibility may be encountered. Compression of the lateral lemniscus may lead to unilateral or bilateral deafness.

Pineal Body.

The symptoms of tumours of the pineal body consist of (1) signs of increased intracranial pressure, (2) signs of pressure upon neighbouring parts of the brain, and (3) in exceptional cases disturbances of growth and development. Since the pineal body is situated between the splenium of the corpus callosum above and the superior corpora quadrigemina below, its enlargement speedily causes internal hydrocephalus, owing to obstruction to the drainage of the third ventricle, and symptoms of compression of the upper part of the midbrain   Signs of increased intracranial pressure therefore occur early and are associated with the signs of a midbrain lesion as described in the previous section, namely, defect of conjugate ocular deviation upwards, less often downwards and laterally; paresis of convergence; retraction or ptosis of the upper lids; inequality of the pupils, which are usually dilated; reflex iridoplegia; bilateral signs of pyramidal lesion, nystagmus and ataxia; tremor and sensory loss, including deafness.

The disturbances of growth are found only when the tumour develops in young boys, and not always then, occurring in only about 14 per cent of all cases. They consist of mental precocity, abnormal growth of the skeleton, and premature development of the genitalia and secondary sexual characteristics, a syndrome which has received the name 'macrogenitosomia praecox'. The cause of these symptoms is unknown.

The internal hydrocephalus caused by a pineal tumour may lead to 'hypopituitarism', and obesity may thus complicate the clinical picture

The Region of the Optic Chiasma.

The small region at the base of the brain lying between the optic chiasma and the cerebral peduncles is the site of tumours arising in four situations, namely, (1) tumours of the pituitary body, (2) tumours of the hypophyseal duct, (3) suprasellar meningiomas, and (4) gliomas of the optic chiasma. Since these tumours are distinguished by differences in the general and focal symptoms to which they give rise it is convenient to consider them separately.

Pituitary Tumours.

As already described, three pathological types of pituitary tumour commonly occur, namely, (i) chromophil, (ii) chromophobe, thus described in terms of the reaction of their cells to eosin staining, and (iii) basophil adenomas. The symptoms of these tumours may be divided into (a) endocrine disturbances which vary according to the pathological nature of the tumour, (b) pressure symptoms, and

(c) alterations in radiographic appearances, which, though varying in severity, are common to the first two tumours in virtue of their situation *within the sella turcica.*

(a) *Endocrine Disturbances.* (i) *Chromophil Adenoma.* In this tumour the eosinophil cells characteristic of the anterior lobe of the normal pituitary predominate, though chromophobe cells may also be present. The endocrine symptoms are commonly regarded as an exaggeration of the normal function of the anterior lobe of the gland, that is to say, as pathological hyperpituitarism. When the tumour arises before growth has ceased, gigantism occurs; when, as more frequently happens, the tumour begins during adult life, acromegaly is the result (Fig. 38). This is characterized by slow changes in the skin and subcutaneous tissues, bones, viscera, general metabolism, and sexual activity. The skin and subcutaneous tissues, especially of the fingers, lips, ears, and tongue, exhibit a fibrous hyperplasia, and paraesthesiae may occur in the fingers. Overgrowth of the bones is most evident in the skull, face, mandible, and at the periphery of the extremities. The calvarium is thickened and the bony ridges and points of attachment of muscles are increased in size. The malar bones enlarge, and as a result of overgrowth of the mandible the lower jaw becomes prognathous and separation of the teeth occurs. The hands become broad and spade-like and hyperostoses may develop on the terminal phalanges ('tufting'). Similar changes occur *in the feet, and the patient frequently notices that he requires a* larger size in gloves and boots. A mild polyneuritic syndrome with paraesthesiae and loss of the tendon reflexes may occur. Kyphosis in the upper dorsal spine is common and hypertrophy of many of the viscera has been described. Sugar metabolism is often disturbed, leading to hyperglycaemia and glycosuria, which frequently responds less to insulin than is the case in diabetes mellitus. The metabolic rate is usually increased and hypertrichosis may be present. Impairment of sexual function *is the rule in both gigantism and acromegaly, impotence in the male and relative or complete amenorrhoea* in the female being the rule. Enlargement of the breasts and lactation persisting for months and occurring even in nulliparous women have been described in association with pituitary tumours, possibly of the chromophil type, though the symptoms of acromegaly are not always conspicuous.

(ii) *Chromophobe Adenoma.* These tumours occur almost exclusively in adult life and according to Cushing are three times as common as the chromophil tumour which is associated with acromegaly. Since both their endocrine and their pressure symptoms are apt to be less obtrusive, the diagnosis is much more likely to be missed. The endocrine symptoms of the chromophobe tumour are usually

ascribed to its destructive effect upon pituitary function, that is, they are regarded as due to hypopituitarism. The first symptom is usually a depression of sexual function, which in women takes the form of
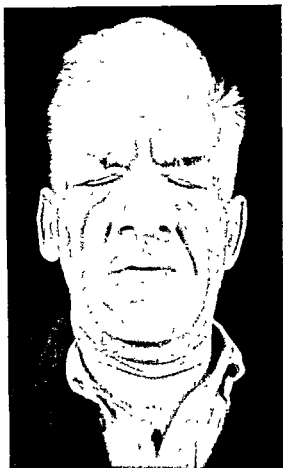

Fig. 38. Acromegaly.

scanty menstruation, progressing to complete amenorrhoea, and in men to impotence. The skin becomes soft and pliable and there is often a loss of hair over the limbs and trunk, and over the face in men. Moderate obesity often develops, associated with a lowered metabolic rate and increased sugar tolerance. These symptoms may be present for many years before pressure symptoms occur.

(III) *Basophil Adenoma.* The basophil adenoma is a rarity and appears never to attain a sufficient size to cause pressure symptoms. It has been found in association with a syndrome (Cushing's syndrome) characterized by remarkable metabolic disorders, but Crooke (1935) has found that a hyaline change in the basophil cells of the *anterior lobe of the pituitary is the only feature common to patients* exhibiting the syndrome hitherto attributed to the basophil adenoma whether this is associated with basophil adenoma of the pituitary, hyperplasia or neoplasm of the suprarenal cortex, or tumour of the thymus. The individuals affected are usually young women, and their symptoms, to which Cushing drew attention, include painful, plethoric adiposity, associated with cutaneous striae and purpuric patches, hirsuties, amenorrhoea, hyperpiesia, erythraemia, and osteoporosis. In a case which I observed the hyperpiesia was associated with albuminuria, a raised blood urea and papilloedema, and hyperglycaemia and glycosuria were also present. Death occurs usually within five years of the onset of symptoms.

(b) *Pressure Symptoms.* Headache is usually an early symptom of pituitary tumour and is more marked as a rule when the tumour is of the chromophil, than when it is of the chromophobe, type. In the early stages it is due to expansion of the sella and is usually described as a 'bursting' headache with a bitemporal distribution. If later the tumour extends beyond the diaphragma sellae the headache is due to general increase of intracranial pressure. Vomiting is usually absent, except in the later stages. Since the optic chiasma lies above the diaphragma sellae, visual field defects are an important and early symptom of pituitary tumours. Usually the tumour as it enlarges upwards first compresses the decussating fibres of the chiasma, hence bitemporal hemianopia is the field defect most frequently encountered (see p. 56). This is as a rule asymmetrical, the defect beginning in the periphery of the upper temporal quadrant on one side, whence it extends towards the fixation point and downwards into the lower temporal quadrant. A similar change occurs either simultaneously or subsequently on the opposite side. In other cases the defect may begin as a scotoma on the temporal side of the fixation point. As the tumour grows, the nasal field of the eye first affected is encroached upon so that the patient often passes through a stage of complete blindness in one eye with a temporal hemianopia on the opposite side. Later, if the pressure is not relieved, the second eye also becomes blind. Less frequently one or other optic tract is compressed before the chiasma with the production of a homonymous hemianopia. Rarely the visual paths escape damage.

Compression of the optic chiasma causes primary optic atrophy

which is often more advanced in one eye than in the other. As the pressure at the same time obliterates the subarachnoid sheath of the optic nerves, papilloedema rarely occurs. In the later stages of the development of the growth ocular palsies may be produced by compression of the third or sixth cranial nerves, and trigeminal pain, usually referred to the first division of the nerve and sometimes associated with analgesia.

Cerebral symptoms do not occur until the tumour has expanded beyond the sella, when compression of the cerebral peduncles may lead to unilateral or bilateral signs of pyramidal defect; uncinate fits may result from compression of the uncinate gyrus and pressure upon the frontal lobe may lead to marked mental deterioration, with or without abnormal emotional reactions.

(c) *Radiographic Appearances.* Adenoma of the pituitary, except the basophil variety, causes a uniform expansion of the sella, with thinning of its walls.

Hypophyseal Epidermoid Tumour.

The pathology of these tumours has already been described. Since they depend upon abnormalities of development, symptoms usually appear at an early age, and in more than one-third of cases the patient comes for treatment before the age of 15. Less frequently, however, they cause no symptoms until middle life. These tumours usually arise above the sellar diaphragm, but exceptionally they develop within the sella itself.

(a) *Endocrine Disturbances.* Since they are situated between the floor of the third ventricle and the pituitary and develop at an early age, they may produce a large variety of disturbances of growth and metabolism, which may be due to their compression either of the pituitary or of the tuber cinereum, or of both these structures. In Cushing's words, 'the patient may show extreme degrees of adiposity or emaciation, of polyuria or the reverse, of dwarfism, of sexual infantilism or of premature physical senility'. In the later stages the patient may be drowsy, and urticaria and hyperpyrexia have not uncommonly followed operative interference with the growth.

(b) *Pressure Symptoms.* Symptoms of increased intracranial pressure are much more conspicuous than in the case of pituitary tumours. When the tumour arises in childhood the skull may be enlarged and the sutures separated. Headache and vomiting may be severe and papilloedema is rather commoner than optic atrophy. The tumour may compress the optic nerves, chiasma, or tracts, leading to corresponding field defects. The optic chiasma is compressed from above, hence the resulting bitemporal hemianopia usually

begins in the lower quadrants. The frontal lobes, temporal lobes, and cerebral peduncles may also be compressed.

(c) *Radiographic Appearances.* These consist of (i) general signs of increased intracranial pressure, such as 'convolutional printing', (ii) erosion of the clinoid processes and flattening of the sella turcica, the result of downward pressure by the tumour, (iii) radiographic evidence of calcification *within the tumour which is present in about* 75 per cent. of cases and varies from faint, opaque flecks to a mass the size of a hen's egg, lying above the sella turcica. Occasionally there are also areas of calcification within the sella.

Suprasellar Meningioma.

Suprasellar meningiomas are tumours of adult life arising from the meninges which cover the circle of venous sinuses around the diaphragma sellae. Headache is not as a rule severe and endocrine symptoms are usually absent. The principal symptoms are visual and are due to compression of the optic nerve, chiasma, or tract, according to the position of the tumour. Primary optic atrophy is the rule and the visual field defects may consist either of hemianopia or a central or temporal paracentral scotoma. One eye is usually affected before the other and to a greater extent. Pressure of the tumour upon the base of the brain may lead to uncinate fits, general convulsions, and hemiparesis. Radiograms may show no abnormality or the optic foramen or clinoid processes may be eroded and the sella flattened, and there may be opacities due to calcification within the growth.

Glioma of the Optic Chiasma.

This is a rare tumour which usually occurs in childhood and may be associated with generalized neurofibromatosis. Owing to the situation of the tumour visual deterioration usually draws attention to its presence before a marked rise of intracranial pressure occurs. Primary optic atrophy is the rule and the visual field defects are often bizarre and may not conform to the familiar bitemporal or homonymous hemianopia. Exophthalmos may occur. Endocrine disturbances are absent. Radiograms usually show enlargement of the sella turcica forwards beneath the anterior clinoid processes.

Cerebellum.

The cerebellum is a common site of tumour, especially in childhood. Medulloblastomas are usually found in the cerebellum and during the first decade of life. They arise in the midline in the region of the roof of the fourth ventricle. Astrocytomas, though they may occur either in the cerebrum or in the cerebellum, are also most

frequently encountered in the latter during childhood and are often cystic. Angioblastomas are almost exclusively cerebellar tumours and are also usually cystic, and a considerable proportion of tuberculomas are found in the cerebellum.

The majority of cerebellar tumours arise in the midline but may extend into one or other lateral lobe. The symptoms differ considerably according to whether the tumour is median or lateral.

(a) *Midline Cerebellar Tumours.* In this group symptoms of increased intracranial pressure occur early and often become severe. Headache, vomiting, and papilloedema are conspicuous and in children hydrocephalus often leads to enlargement of the skull, with separation of the sutures and symptoms of 'hypopituitarism'. Symptoms of cerebellar deficiency are usually most marked in standing and walking and there may be little or no ataxia of the upper limbs. Giddiness is common and there is usually unsteadiness in standing, especially with the eyes closed. The patient usually tends to fall backwards, sometimes forwards. The gait tends to be ataxic, especially on turning. Nystagmus is often absent, but there is usually muscular hypotonia which may be unequal in degree upon the two sides of the body. Compression of the midbrain may lead to 'tonic fits' characterized by extension of all four limbs and opisthotonos, with loss of consciousness, and the pupils are occasionally dilated and exhibit sluggish reactions, a misleading sign which may suggest a tumour of the third ventricle or pineal body. The remaining cranial nerves are often little affected, though weakness of one or both external recti and slight facial weakness may be encountered. There is as a rule little weakness of the limbs, though an extensor plantar response on one or both sides may be found. The tendon reflexes may be sluggish, probably as a result of raised intracranial pressure. Sensory loss is exceptional.

(b) *Tumours of the Lateral Lobe.* As in the case of midline cerebellar tumours signs of increased intracranial pressure occur early. Nystagmus is usually marked and is most evident on conjugate lateral ocular deviation to the side of the lesion. The quick phase is directed towards the periphery and the slow phase towards the centre. Nystagmus is usually confined to the plane in which the eyes are deviated, but may occasionally be rotary. Other signs of a deficiency of cerebellar function are most marked in, and often confined to, the limbs on the side of the lesion. Hypotonia is usually conspicuous. The outstretched upper limb on the affected side tends to sway if unsupported. Ataxia is present on the affected side, being most evident in the upper limb on carrying out fine movements, for example in the finger-nose test, and in the lower limb in walking. The gait is unsteady. The patient tends to walk with a wide base and

deviate to the affected side, and is liable to fall to the affected side when standing with the feet together and the eyes closed. Rapid alternating movements are carried out with the affected limb in an irregular, jerky manner or may even be impossible. The shoulder on the affected side is often at a lower level than the normal shoulder and there may be scoliosis with the concavity towards the side of the lesion

There is frequently an abnormal attitude of the head, which is flexed to one side and rotated so that the occiput is directed towards the shoulder, towards which the head is flexed. This rotated, or, as it is sometimes called, 'cerebellar', posture of the head may occur in the absence of a lesion of the cerebellum and is due to an interruption of afferent impulses derived from the otolith organs of the internal ear. In the early stages of a lateral cerebellar tumour the head is usually flexed and rotated to the side of the lesion. Later, when the tumour is sufficiently large to exert pressure upon the brain-stem, the head is rotated to the opposite side. Speech is usually little affected in cerebellar tumours, whether of the midline or lateral lobes. (For other symptoms of cerebellar deficiency see p 48)

The symptoms of cerebellar deficiency associated with a tumour of the cerebellum often appear to be disproportionately slight with reference to the size of the tumour. It is known that after ablation of the cerebellum a considerable recovery of function may occur, and it is probable that the slow growth of the tumour permits a gradual compensation for cerebellar deficiency by other parts of the nervous system

Neighbourhood symptoms are usually more conspicuous in the case of lateral cerebellar tumours than when the tumour is in the midline. Forward pressure by the tumour may cause a disturbance of function of any of the cranial nerves from the fifth to the twelfth on the same side, the fifth, sixth, and seventh being most frequently affected. Pressure upon the ipsilateral half of the pons and medulla not infrequently leads to slight signs of pyramidal defect on the opposite side of the body and occasionally to sensory loss, especially impairment of postural sensibility, though this is rarely marked.

Eighth Nerve.

Tumours of the eighth nerve (acoustic neuromas) may be either unilateral or bilateral. In the latter case they are usually manifestations of multiple neurofibromatosis. They rarely give rise to symptoms before the third decade of life and most commonly during the fifth decade. Symptoms of increased intracranial pressure are usually late in developing. Owing to the situation of the tumour upon the

eighth nerve the first symptoms are due to a disturbance of the functions of this nerve, and this feature is so constant that if a tumour situated in the cerebello-pontine angle manifests itself through some other inaugural symptom it is not safe to make a diagnosis of acoustic neuroma. Tinnitus is usually the first symptom, followed by progressive deafness, though sometimes labyrinthine symptoms, for example giddiness, precede disturbances of hearing. It is not uncommon to find that a patient when he first comes under observation is completely deaf in the affected ear and exhibits no response to caloric tests of labyrinthine function on the side of the tumour. Headache at first is usually occipital, but sometimes frontal, and tends to radiate from back to front through the mastoid region. In the late stages it becomes general and there may be attacks of severe occipital pain radiating down the spine and associated with retraction of the head and neck, respiratory embarrassment, and, sometimes, loss of consciousness. Papilloedema and vomiting are comparatively late in developing. The patient may complain of paraesthesiae referred to the face on one or both sides, and attacks of facial spasm may occur. Diplopia is not uncommon. Dysphagia is a late symptom.

On examination there are signs of impaired conductivity in the affected eighth nerve. Hearing is much reduced and may be completely lost, and there is often loss of all response to caloric tests of labyrinthine function on the affected side. This is often associated with loss of reactions from the vertical canals, but not from the horizontal canal on the opposite side owing to pressure by the neuroma upon the pons, where the decussated fibres from the opposite vertical canals lie more superficially than those from the horizontal canal. The head is often rotated so that the occiput is directed towards the shoulder of the affected side.

Other signs result from pressure by the tumour upon neighbouring cranial nerves. There is usually some facial weakness on the affected side, though this may be slight. Sensory loss may occur in the trigeminal distribution, but reduction or loss of the corneal reflex may be the only sign of involvement of the fifth nerve. Weakness of the external rectus may be present as a result of compression of the sixth nerve. The remaining cranial nerves are usually unaffected. Disturbance of function of the fifth, sixth, seventh, and eighth cranial nerves may occur on the opposite side as well as on the side of the tumour. Compression of the ipsilateral cerebellar hemisphere causes symptoms of cerebellar deficiency on the side of the tumour. Signs of compression of the brain-stem are not as a rule conspicuous, but crossed hemiparesis and hemianaesthesia may occur as a result of compression of the long descending and ascending tracts, and weakness of

conjugated ocular deviation to the side of the tumour, as a result of compression of the pons. Radiographic examination may show erosion of the petrous portion of the temporal bone or of the internal auditory meatus by the tumour.

Pons and Medulla.

Owing to the close association of the pons and medulla of important cranial nerve nuclei as well as of the descending and ascending fibre tracts, tumours in this region early give rise to localizing signs and symptoms. Possibly for this reason signs of increased intracranial pressure are often slight when the patient first comes under observation. Vomiting is often absent and papilloedema appears in under 50 per cent. of cases. Headache, which in the early stages is mainly occipital, and vertigo are common and both may be intensified by rotation of the head. Diplopia and weakness or incoordination of the limbs are early symptoms. At first the signs may point to a lesion confined to one-half of the brain-stem but they soon become bilateral. Weakness of the external rectus on one or both sides usually develops early and may be followed by paresis of conjugate ocular deviation, or the latter may occur alone. 'Crossed paralysis' is usually seen at an early stage, the distribution of the paresis on the two sides of the body depending upon the level of the tumour. Most frequently there is weakness of the jaw and facial muscles on one side and of the soft palate, tongue, and limbs on the other. Later bilateral paralysis of the bulbar muscles and limbs usually develops. Sensory loss in the region of the trigeminal distribution with reduction of the corneal reflexes is usually present on one or both sides, and impairment of hearing may occur. Sensory loss on the limbs and trunk is variable. Analgesia and thermo-anaesthesia may occur without loss of postural sensibility or vice versa, or all forms of sensibility may be affected. Sensory changes may be predominantly unilateral or bilateral. Nystagmus and some degree of ataxia of the limbs are common, even though the cerebellum is not itself invaded. A rotated posture of the head is not uncommon, the head being flexed and rotated towards the side less affected by the tumour. Paralysis of the ocular sympathetic on one or both sides is frequent and the visceral functions of the medulla may be disordered, leading to tachycardia or cardiac irregularity, *alterations in the respiratory rate and rhythm, hiccup, and glycosuria.*

Fourth Ventricle.

Tumours arising in the fourth ventricle itself are usually ependymomas originating in the ependymal cells, though the fourth ventricle may be invaded by tumours arising in the vermis of the

cerebellum or in the pons. Headache is an early symptom and is liable to paroxysmal exacerbations, the pain radiating to the neck and even to the shoulders and arms. Vomiting and papilloedema and other evidences of hydrocephalus usually develop rapidly. There is often stiffness of the cervical muscles and the head may be flexed and rotated to one side. Disorders of equilibrium are prominent. The patient often tends to fall backwards, and gait is ataxic. Symptoms of cerebellar deficiency in the limbs may be slight or absent. 'Tonic' fits may occur. Disturbance of function of the cranial nerves is often slight, though there may be paresis of one or both external recti and trismus may occur. The tumour may lead to disturbances of the visceral centres of the medulla, causing attacks of tachycardia, dyspnoea and irregular respiration, hiccup, sweating and vasomotor disturbances, polyuria and glycosuria. Sudden death may occur.

In some cases the tumour grows out from the fourth ventricle and surrounds and compresses the spinal cord at the level of the foramen magnum, producing analgesia and thermo-anaesthesia of the face and upper limbs, with signs of pyramidal involvement, and leading to a clinical picture closely resembling syringobulbia. In such cases Queckenstedt's test may reveal a blockage of the subarachnoid space.

Basal Meninges.

Neoplastic infiltration of the basal meninges leads to a distinctive clinical picture. This condition may be due to metastases from extracranial neoplasms or to extension to within the cranial cavity of a primary carcinoma of a nasal sinus or of a nasopharyngeal endothelioma. It leads to progressive cranial nerve palsies, which are usually bilateral but often asymmetrical. Papilloedema may be present or absent. Invasion of the pituitary and tuber cinereum may cause polyuria, drowsiness, and other symptoms of hypothalamic disturbance. In some cases cervical rigidity and pyrexia are present, the clinical picture then resembling that of tuberculous meningitis. Neoplastic infiltration of the basal meninges may be associated with focal symptoms due to metastases within the brain. In all three of the forms of neoplasm described above there may be metastases in the cervical glands.

DIAGNOSIS

Other conditions may be confused with intracranial tumour, either because they give rise to increased intracranial pressure or because they lead to a progressive cerebral lesion, or for both of these reasons. The following are the conditions most likely to be mistaken for a growth.

(1) *Intracranial Abscess.*

In most cases intracranial abscess is readily distinguished from tumour, since its development is usually acute or subacute and a primary focus of infection is almost always to be found either in the neighbourhood of the brain or elsewhere. Rarely, however, a chronic abscess may arise, its source of infection being latent or having disappeared. In such cases the diagnosis from tumour may be impossible and the nature of the lesion may be unsuspected until operation. A sudden or apoplectiform onset, the occurrence of a leucocytosis in the blood and of a slight pleocytosis in the cerebro-spinal fluid, and the presence of slight pyrexia are points in favour of an abscess, but none of these is constantly present.

(2) *Arachnoiditis.*

The terms 'arachnoiditis', 'meningitis circumscripta serosa', and 'cerebral pseudo-tumour' have been applied to a condition the pathogenesis of which is obscure, but which in some cases at least is probably inflammatory in origin, and which recently has been observed to follow acute lymphocytic chorio-meningitis. Localized cystic collections of cerebro-spinal fluid in the subarachnoid space may be indistinguishable from intracranial tumour before operation. Not uncommonly they occur in the cerebello-pontine angle and at the base of the brain, where the optic chiasma may be involved. Pre-operative diagnosis from tumour may be impossible.

(3) *Hydrocephalus.*

Congenital hydrocephalus will not give rise to difficulty, nor will hydrocephalus following meningitis. Hydrocephalus due to intracranial venous sinus thrombosis usually leads to conspicuous papilloedema with little headache and vomiting, and focal signs are usually absent.

(4) *Cerebral Arterial Disease.*

Cerebral arteriosclerosis gives rise to confusion when papilloedema coexists with signs of a progressive cerebral lesion. The papilloedema in these cases is usually slight and tends to persist unchanged for long periods and is associated with marked arteriosclerotic changes in the retinal vessels. Cerebral softening due to vascular occlusion may cause symptoms apparently referable to a single lesion, though there is frequently evidence that the lesions are multiple. The onset of symptoms with a slight 'stroke' is valuable evidence of their vascular origin, and confirmation is found in evidence of arteriosclerosis elsewhere. In 'malignant hypertension' severe headache and papilloedema may coexist with a focal cerebral lesion, but the

blood-pressure is high. In some cases the diagnosis remains in doubt until ventriculography demonstrates the absence of a space-occupying lesion, and it must be remembered that in later life an intracranial tumour may coexist with arteriosclerosis and raised blood-pressure.

(5) *Intracranial Aneurysm.*

Intracranial aneurysm may simulate tumour either before it ruptures or after recovery from the immediate effects of rupture. Before rupture it may exert pressure upon surrounding structures, but the resulting signs are only very slowly progressive; headache is slight and papilloedema is usually absent at this stage. After recovery from rupture, headache, secondary optic atrophy, and sometimes focal cerebral symptoms may closely simulate tumour. The history of the onset of the symptoms and their non-progressive character should help in establishing the correct diagnosis which may be confirmed by angiography with thorotrast.

(6) *Neurosyphilis.*

The meningo-vascular form of neurosyphilis may be mistaken for tumour on account of the presence of headache and papilloedema associated with an intracranial lesion, while the mental deterioration and convulsions of general paralysis may suggest a tumour of the frontal lobe or corpus callosum. In both forms of neurosyphilis, however, reflex iridoplegia is likely to be present, and the Wassermann reaction and other characteristic changes in the cerebro-spinal fluid reveal the true nature of the disorder. The same is true of syphilitic hydrocephalus which may cause headache and papilloedema. Gumma of the brain is extremely rare, and the co-existence of symptoms of an intracranial tumour with a positive Wassermann reaction must not be regarded as necessarily or even probably indicating that the patient is suffering from cerebral gumma. Syphilis and cerebral tumour sometimes occur in the same individual.

(7) *Epilepsy.*

Since generalized epileptiform convulsions are a common symptom of intracranial tumour, the differential diagnosis of tumour from epilepsy frequently arises. Idiopathic epilepsy usually begins before the age of 25. Convulsions beginning after this age should always suggest the possibility of tumour, though in late middle life and old age cerebral arteriosclerosis is the commonest cause. In epilepsy headache is absent, except immediately after the fits, and signs of a focal lesion of the nervous system are usually absent, and if present are non-progressive. A focal onset of the fits is of no diagnostic value, since it is not peculiar to intracranial tumour.

(8) *Migraine.*

Headache, vomiting, visual hallucinations, and visual field defects are common both in migraine and to tumours in the neighbourhood of the visual cortex of the occipital lobe, especially angioma. As a rule the field defects of migraine are transitory, lasting only for from one-half to one hour, but occasionally an exceptionally severe attack is followed by a permanent scotoma or hemianopia. Usually migraine begins at puberty, and there is often a family history of the disorder. Signs of increased intracranial pressure are absent and there is no evidence of a progressive intracranial lesion.

(9) *Retrobulbar Neuritis.*

Acute bilateral retrobulbar neuritis may simulate intracranial tumour, because it causes papilloedema with impairment of vision. It is distinguished, however, by the fact that the visual loss is disproportionately great compared with the papilloedema, which is usually slight. Moreover, the field defect is central, whereas in papilloedema due to increased intracranial pressure it is peripheral. Headache is absent in retrobulbar neuritis, but pain in the eyes may be considerable and they are usually tender on pressure.

(10) *Disseminated Sclerosis.*

Disseminated sclerosis is likely rarely to be confused with tumour, but difficulty may arise when a patient suffering from the former exhibits papilloedema or suffers from epileptiform convulsions or presents the signs of a progressive focal cerebral lesion. In such cases stress must be laid upon the frequent occurrence of remissions in the history in disseminated sclerosis and the rarity of headache in this disorder. A careful search must be made for evidence of multiple lesions in the nervous system, and a positive colloidal gold curve in the cerebro-spinal fluid would be of diagnostic value.

(11) *Diffuse Sclerosis.*

Diffuse sclerosis may simulate tumour when papilloedema is present. However, the onset in early life, usually with visual failure of subcortical origin, and the bilateral distribution of the symptoms should enable the two conditions to be distinguished.

DIAGNOSIS OF THE NATURE OF THE TUMOUR

When the presence of an intracranial tumour has been diagnosed, an attempt should always be made to decide its probable pathological nature, since upon this may depend whether surgical interference is to be undertaken and the nature of the difficulties likely to be encountered by the surgeon.

To form an opinion as to the nature of the growth, it is necessary to take into account the age of the patient, the length of the history, the situation of the lesion, the degree of increased intracranial pressure, the radiographic appearances of the skull, and the presence or absence of associated abnormalities in other parts of the body. This section is therefore an attempt to correlate the pathological nature of the commoner types of intracranial tumour with their clinical features.

Medulloblastoma.

This is a rapidly growing, malignant tumour, most frequently found in the neighbourhood of the roof of the fourth ventricle in childhood. It should be suspected in children who present the symptoms of a midline cerebellar tumour with a history of less than a year's duration.

Spongioblastoma.

This is a malignant and rapidly growing tumour arising in middle life and usually found in the cerebral hemispheres. It should be suspected in middle-aged persons presenting the symptoms of a tumour of one cerebral hemisphere with a history of less than a year's duration

Astrocytoma.

The astrocytoma is a slowly growing tumour which may arise either in the cerebral or cerebellar hemispheres. In most cases in which the history of an intracranial tumour in either of these situations extends over several years, the growth is an astrocytoma. Owing to its situation, the cerebellar astrocytoma is likely to bring the patient under observation sooner than one situated in the cerebral hemisphere

Meningioma.

Meningiomas are almost exclusively supratentorial tumours and exhibit certain sites of election which have already been described. They are rare before middle life. Owing to their extracerebral origin they compress but do not invade the brain. The focal symptoms to which they give rise are therefore less severe in relation to the size of the tumour than is the case with the gliomas. Meningiomas, therefore, frequently cause a marked increase in intracranial pressure, with comparatively slight signs of a focal lesion. Their proximity to the skull leads to erosion of bone in 20 per cent. of cases, and this is often demonstrable on radiographic examination, which may also show calcification within the tumour. The meningiomas are usually

associated with increased vascularity, which may be extracranial as well as intracranial, the latter being visible radiographically.

Angioma.

The angiomas, which probably originate in a congenital vascular abnormality, usually yield a long history and, owing to their situation on the cerebral cortex, epileptiform attacks are common Facial naevus may be associated with venous angioma, and increased extracranial vascularity is often observed in connexion with arterial angioma, which may yield a bruit on auscultation of the skull.

Angioblastoma.

These tumours are almost exclusively cerebellar and are sometimes associated with angioblastoma of the retina and with cysts of the pancreas and kidneys and hypernephromas of the kidneys or suprarenal glands. Only the first of these associated abnormalities, however, is likely to be discoverable clinically.

Pituitary and Suprapituitary Tumours.

The diagnosis of the pathological nature of these tumours is described in the section dealing with their symptomatology.

Acoustic Neuroma.

The clinical picture of this tumour, which commonly arises in middle-aged persons, is highly distinctive, since the first symptoms are those of destruction of the eighth nerve on one side

Metastatic Tumours.

Metastatic tumours should be suspected in middle-aged or elderly individuals who present the history of a rapidly developing intracranial growth. In all such cases a thorough clinical and radiographic search for a primary neoplasm should be made. A history of marked loss of weight is suggestive. Not infrequently an intracranial metastasis gives rise to symptoms before the primary lesion, especially when this is in the lung, and sometimes the primary lesion is not discovered until autopsy.

Tuberculoma.

Tuberculoma may occur at any age, but is most frequent in childhood and early adult life It begins as a circumscribed patch of tuberculous leptomeningitis and is therefore cortical or subcortical in the cerebral and cerebellar hemispheres and first involves the superficial regions when it is situated in the brain-stem. Remissions and relapses in the development of symptoms are some-

what characteristic, and increase in intracranial pressure is often disproportionately slight. A pleocytosis may be found in the cerebrospinal fluid. The presence of a tuberculous lesion elsewhere will afford confirmatory evidence, but this is so common that it may coexist with a glioma.

Gumma.

Gumma is a very rare tumour of the brain. Both glioma and syphilitic infection are comparatively common and both may occur in the same individual. The association of a positive Wassermann reaction with the symptoms of an intracranial growth should not be interpreted as meaning that the latter is necessarily or even probably a gumma. Intracranial gumma usually responds little to antisyphilitic treatment. It cannot safely be diagnosed before operation.

Parasitic Cysts.

The possibility that the symptoms of an intracranial tumour may be due to parasitic cysts should always be considered in a patient who has lived abroad. The presence of such cysts elsewhere in the body affords strong confirmatory evidence. The blood may exhibit an eosinophilia, and complement fixation and flocculation tests and Cason's intradermal sensitization test may be of diagnostic value in suspected cases of hydatid infection.

PROGNOSIS

The prognosis of intracranial tumour is influenced by the nature of the growth and its accessibility to the surgeon.

In the absence of surgical interference almost all intracranial tumours increase in size, their rate of growth depending upon their nature. The resulting increase of intracranial pressure and destruction of brain tissue ultimately prove fatal. When papilloedema is severe, death may be preceded by blindness. The more malignant gliomas, such as the medulloblastomas and the spongioblastomas, grow rapidly and usually prove fatal within a year. The slowly growing astrocytomas may cause symptoms for many years before leading to a marked increase in intracranial pressure.

Sudden death in cases of intracranial tumour is rare, but is an eventuality which should always be borne in mind. It may occur in *the absence of marked papilloedema, though there is usually a history* of headaches of increasing severity. The patient may without warning become first drowsy and then comatose and die within a few hours of losing consciousness.

The recent development of neuro-surgical technique has greatly increased the range of cerebral surgery, and in the best hands the

immediate mortality of operations for the removal of intracranial tumour is under 10 per cent. *Extracerebral tumours can frequently be removed without damage to the underlying brain*, and in such cases complete recovery may occur. Removal of an *intracerebral tumour*, on the other hand, necessitates considerable cerebral trauma. The risk of *residual symptoms is proportionately increased*. Mental deterioration and aphasia are likely to follow the removal of a large intracerebral tumour of the left hemisphere. Tumours in the interpeduncular region are relatively inaccessible to surgery, and tumours which infiltrate the brain-stem cannot be removed. The more malignant the tumour, the greater the likelihood of its recurrence after its attempted removal. Recurrence of the more rapidly growing gliomas is the rule and even meningiomas may recur. The angiomas have so far proved unamenable to surgical treatment, but good results have been obtained in the case of the angioblastomas, especially when they are cystic and the mural nodule is completely removed.

The prognosis is naturally bad in the case of metastatic tumours on account of the primary growth and the frequency of metastases elsewhere.

Tuberculomas may become quiescent. If they are not too large they lend themselves to complete removal, though there is a risk that tuberculous meningitis may follow the operation.

Cairns (1936) has investigated the after-results in a series of 157 patients operated upon by Cushing. Seven to nine years later 63 were alive and 37 were leading a useful life. All the patients with spongioblastoma multiforme and cerebellar medulloblastoma died within two years of operation, and only one patient with a cerebral astrocytoma had survived.

TREATMENT

The treatment of election of an intracranial tumour is its surgical removal, though for the reasons given in the previous section this is not always practicable. When a tumour is surgically inaccessible cerebral decompression, by abolishing the rigidity of the skull, lowers the intracranial pressure and relieves headache and papilloedema, thus frequently preserving vision and rendering the patient more comfortable. Right subtemporal decompression should be carried out in the case of supratentorial tumours and suboccipital decompression in the case of those situated below the tentorium.

The surgery of the brain has lately become increasingly specialized, and an operation for an intracranial tumour should not be lightly undertaken. Even when the presence of an intracranial growth has been definitely established surgical treatment is not always immediately necessary. The principal indications for operation are:

threatened visual failure, due to papilloedema or optic atrophy from compression of the optic nerves or chiasma, severe headache, and, in the absence of these symptoms, the presence of a surgically accessible tumour which offers good prospects of removal.

Intracranial gumma responds little, if at all, to antisyphilitic treatment and the indications for surgical interference are the same as in the case of intracranial neoplasms.

It is doubtful if the mere presence of an intracranial tuberculoma justifies operation, since tuberculomas may become quiescent and there is a risk that the operation may be followed by tuberculous meningitis. Operation should not be carried out, therefore, unless there is evidence of increased intracranial pressure.

The scope of radiotherapy in the treatment of intracranial tumour is as yet undefined. X-ray irradiation may retard the growth of pituitary adenoma and of some gliomas, especially medulloblastoma of the cerebellum In the latter case it should be used in association with surgical treatment. Little is known as yet concerning the value of radium in the treatment of intracranial tumour.

Dehydration is of value for the temporary reduction of increased intracranial pressure and also as a palliative measure in inoperable cases. Dehydration is especially useful in emergencies, for example to restore to consciousness a semi-comatose patient, in order that a complete clinical examination may be carried out; to combat rapidly developing cerebral oedema and to lower the intracranial pressure in a patient awaiting operation. The simplest and usually a completely effective method of lowering the intracranial pressure is the rectal injection of 8 oz. of a 25 per cent. solution of magnesium sulphate The solution is warmed to the body temperature and the patient should retain it, if possible, for half an hour.

To obtain a more rapid reduction of the intracranial pressure it is necessary to inject a hypertonic solution intravenously. Either 70 c cm. of 15 per cent. solution of sodium chloride in distilled water or 100 c cm of 50 per cent. sucrose solution may be used. The solution should be injected very slowly at a rate of not more than 3 c.cm. per minute As palliative treatment, either before or after operation, magnesium sulphate may be given by the mouth in ½-1 drachm doses thrice daily. Whatever method of dehydration is employed it is important that the patient's intake of water should be restricted to a minimum.

There is no evidence that medical treatment has any effect in retarding the growth of an intracranial tumour.

Intensive antisyphilitic treatment should be carried out when the presence of a gumma is suspected, but operation should not be postponed too long.

In cases of tuberculoma every effort should be made to build up the patient's resistance to the infection, as in the case of other tuberculous lesions.

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3. HEADACHE

The Investigation of a Case of Headache.

Headache is one of the commonest symptoms. Though it is frequently a trivial disorder, it is also at times a symptom of the gravest significance. Every patient suffering from headache requires, therefore, a thorough investigation. In taking the 'history', attention must be paid to the following points. How long has the patient suffered from headache? Is it increasing in severity? Is it constant or paroxysmal, and if paroxysmal what is the duration of the paroxysms, and do they occur at any special time of day? Are they precipitated by any circumstance or activity, and how, if at all, can they be relieved? What is the character of the headache, and what is its situation? Is it associated with tenderness of the scalp or skull, with visual disturbances, vomiting, or vertigo? Has there been an injury of the head? Are there symptoms of nasal obstruction or of a discharge, either from the nostrils or into the pharynx? Is there a history of syphilis?

The investigation of a case of headache involves a complete examination of all the organs of the body, special attention being paid to the ocular fundi, the nose and nasal air sinuses, the blood-pressure, and the urine. Radiography of the skull, including the nasal sinuses, and examination of the cerebro-spinal fluid and blood Wassermann reaction may be required.

The Causes of Headache.

(1) *Disease of the Bones of the Cranium.*

Osteitis of the cranial bones is an occasional cause of headache. Syphilitic osteitis and osteitis deformans of Paget should especially be borne in mind. Headache due to osteitis is of a burning, boring character and is associated with tenderness of the skull, which often feels warmer than normal. Local or general thickening of the cranium is often present, and the characteristic changes in the bones are demonstrable by radiography. Oxycephaly, which may cause headache owing to premature synostosis of the sutures, is readily recognized by the abnormal shape of the skull.

(2) *Neuritis and Neuralgia.*

Pain in the head may be due to neuritis and neuralgia of the sensory nerves of the scalp. The supra-orbital, auriculo-temporal, posterior auricular, and great occipital nerves may be the site of such processes. The pain in such cases is usually paroxysmal and radiates along the course of the nerve, which is tender on pressure. Cutaneous hyperalgesia corresponding to the sensory distribution of the nerve affected is occasionally present. Tic douloureux is a form of trigeminal neuralgia which may involve the scalp when it attacks the first division of the nerve. This, however, is less frequently involved than the second and third divisions. Herpes zoster of the Gasserian ganglion *is sometimes a cause of severe and persistent neuralgic pain.* In the acute stage there is a vesicular eruption on an erythematous base, which appears on the forehead, vertex, and sometimes the side of the nose, when the first division is involved, and the cornea may also be affected. After the acute stage the scars of the eruption remain visible, and there is usually cutaneous anaesthesia. Pain in the distribution of the trigeminal nerve may be due to pressure upon it in its intracranial course by intracranial neoplasm or aneurysm, or to its involvement in meningo-vascular syphilis or tabes. Moreover, its central fibres may be involved in a lesion within the medulla. Thrombosis of the posterior inferior cerebellar artery, syringobulbia, and disseminated sclerosis may in this way cause neuralgic pain over the face and scalp.

(3) *Referred Pain*

Lesions of many viscera are attended by pain referred to the superficial tissues remote from the viscus involved but innervated by the same segment of the nervous system In this way visceral disease in many situations may be attended by pain in the head and localized hyperalgesia of the face or scalp. These symptoms may be produced by eye-strain, iritis, glaucoma, lesions of the middle ear, nasal sinuses, teeth, pharynx, and tongue, and also by disease of the intrathoracic and intra-abdominal viscera (see p 815). The explanation of this reference of pain to the head from remote organs is that the trigeminal is the somatic sensory nerve corresponding to the vagus by which so many viscera are innervated. Nasal obstruction, apart from infection of the nasal sinuses, is a common cause of persistent frontal headache. Occipital headache is often present in cases of cervical fibrositis and spondylitis.

(4) *Meningeal Irritation.*

Meningeal irritation is responsible for some of the severest headaches. It may be due to the various forms of meningitis, including syphilitic meningitis, or to the presence of non-infective irritant

products such as extravasated blood in contact with the meninges. The pain is constant, severe, and throbbing or 'bursting', and is usually associated with hyperalgesia of the scalp, and in the case of acute meningitis with other signs of meningeal irritation, such as cervical rigidity and Kernig's sign.

(5) *Headaches of Vascular Origin.*

High blood-pressure causes paroxysmal throbbing or 'bursting' headaches Intracerebral haemorrhage results in an increase in the mass of the brain, which leads to headache if the patient remains conscious. Cerebral embolism and thrombosis cause headache owing to the oedema of the infarcted area of the brain. Intracranial aneurysm is rarely large enough to cause increased intracranial pressure before rupture. It may cause pain in the head, however, by compression of the trigeminal nerve. After rupture, subarachnoid haemorrhage leads to headache by causing both increased intracranial pressure and meningeal irritation.

Changes in the calibre and permeability of the cerebral vessels are probably responsible for the headaches which accompany numerous toxic states such as severe infections, alcoholic over-indulgence, general anaesthetics, uraemia, and diffuse cerebral inflammations, the various forms of encephalitis.

Migraine is probably also a vasomotor disorder, and on this hypothesis the headache is due to vascular dilatation following a preliminary constriction. The characteristics of migrainous headache are described on p. 844.

Headache may be caused by arteritis of the superficial temporal artery

Headache may also be produced by raised intracranial venous pressure When this is caused by thrombosis of an intracranial venous sinus it is associated with other signs and symptoms which render its nature obvious. When the cause of the raised venous pressure is extracranial the source of the headache may be missed. Severe paroxysmal 'bursting' headaches may thus accompany large goitres, chronic emphysema, and intrathoracic neoplasm and aneurysm.

(6) *Intracranial Neoplasm.*

The mode of production of headache by intracranial neoplasm and its characteristics are considered elsewhere (see pp. 228–31).

(7) *Intracranial Abscess.*

Chronic intracranial abscess leads to headache which is indistinguishable from that produced by intracranial neoplasm. More frequently intracranial abscess is subacute and the headache tends to be constant and of increasing severity.

(8) *Trauma.*

In the more severe degrees of head injury headache is apt to be masked by impaired consciousness. It is a prominent symptom of persistent cerebral contusion, and *in this condition is paroxysmal,* tends to be precipitated by excitement, by exertion, and by stooping, and is often associated with irritability, nervousness, and giddiness.

(9) *Increased pressure of cerebro-spinal fluid.*

This occurs secondarily in many conditions associated with increased intracranial pressure. It is the essential feature of hydro-cephalus. Headache in this condition has the general characteristics distinctive of headache in increased intracranial pressure.

(10) *Lowered intracranial pressure.*

This may cause headache, as, for example, after lumbar puncture. Such headache is throbbing and may be literally prostrating, since it is intensified by sitting or standing and relieved by lying flat or with the feet raised above the level of the head. The pain may radiate *from the head to the neck or dorsal spine.* '*Low pressure*' headache sometimes occurs in persons suffering from anaemia and from low blood-pressure, and is induced in some individuals by taking saline purgatives.

(11) *Psychogenic Headache.*

Numerous abnormal cranial sensations are described by neurotic and psychotic patients. The commonest is a sense of pressure at the vertex, frequently encountered in anxiety states. Or the patient may describe a sensation 'like a nail or wedge being driven into the skull'. Persistent 'neuralgic' pains associated with hyperaesthesia of the scalp and failing to respond to all analgesics may be encountered in hysteria. Patients suffering from depressive states sometimes describe 'terrible pains in the head' of which they can give no more precise description.

Treatment.

Apart from palliative treatment with analgesics such as aspirin, pyramidon, and phenacetin, which can safely be used in most cases, the treatment of headache is that of the causal disorder.

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DISORDERS OF THE CEREBRAL CIRCULATION

I. THE ARTERIAL BLOOD-SUPPLY

THE intracranial blood-supply is derived from the two internal carotid arteries and the two vertebral arteries which unite anteriorly to form the basilar artery. The circle of Willis which is situated at the base of the brain is formed by anastomoses between the internal carotid artery, the basilar artery, and their branches, as follows.

The basilar artery divides into the two posterior cerebrals, which are joined to the two internal carotids by the posterior communicating arteries. The internal carotids give off the two anterior cerebral arteries, which are united by the single anterior communicating artery, which thus completes the circle.

The principal intracranial arteries and their areas of distribution are as follows.

Arteries of the Cerebral Hemispheres.

The Internal Carotid Artery. The internal carotid artery after entering the cranium gives off small branches to the wall of the cavernous sinus, the third, fourth, fifth, and sixth cranial nerves, including the Gasserian ganglion, the pituitary, and the dura mater of the middle fossa. The next branch is the *ophthalmic artery*, from which the central artery of the retina is derived. The internal carotid next gives off the *posterior communicating artery*, which unites it with the posterior cerebral artery. The posterior communicating artery supplies the optic chiasma, pituitary, tuber cinereum, and hypothalamic region, the lower part of the anterior third of the posterior limb of the internal capsule, part of the external nucleus of the optic thalamus, the anterior third of the crusta, and part of the midbrain, including the corpus Luysii and Forel's field. The *anterior choroid artery* passes backwards and, outwards from the internal carotid to enter the anterior extremity of the descending horn of the lateral ventricle, where it supplies the choroid plexus. It is distributed also to the optic tract, to the uncinate gyrus, to the posterior two-thirds of the posterior limb of the internal capsule, and the origin of the optic radiation, to part of the lenticular nucleus, and sometimes to the anterior third of the crusta, which is usually supplied by the posterior communicating, sometimes also to the posterior two-thirds of the crusta, which is usually supplied by the posterior cerebral.

The Anterior Cerebral Artery. The anterior cerebral artery passes forwards and medially from the internal carotid, turns round the genu of the corpus callosum, above which it runs backwards to terminate posteriorly, usually one inch anteriorly to the parieto-occipital fissure. It gives off the following principal branches: (1) Basal branches, of which the most important is the recurrent branch (Heubner's artery). This branch enters the anterior perforated spot and supplies the anterior part of the caudate nucleus, the anterior one-third of the putamen, and the anterior limb of the internal capsule. (2) The anterior communicating artery, which is a short branch uniting the two anterior cerebrals and which gives off no branches. (3) Branches to the frontal and parietal lobes. These supply the medial aspect of the hemisphere and the upper part of its lateral aspect for from three-quarters to one inch from the median edge throughout the length of the artery and a corresponding area of the white matter of the frontal and parietal lobes, including the olfactory tract and lobe. The most important cortical branch of the anterior cerebral is the paracentral artery, which supplies the paracentral lobule, which contains the leg area of the motor cortex. Other branches of the anterior cerebral pass downwards to supply the genu, rostrum, and body of the corpus callosum.

The Middle Cerebral Artery. The middle cerebral artery passes laterally from the internal carotid in the stem of the fissure of Sylvius to the surface of the Island of Reil, where it divides into its terminal cortical branches. When crossing the base of the brain it gives off its basal branches, the lenticular, the lenticulo-optic, and the lenticulo-striate arteries. These branches supply part of the lenticular nucleus, the upper part of both anterior and posterior limbs of the internal capsule, and the horizontal part of the caudate nucleus behind the head. The cortical distribution of the middle cerebral artery is co-terminous with that of the anterior cerebral as far back as the middle of the superior parietal lobule. It then extends to the edge of the median surface or is bounded by the territory of the posterior cerebral artery, passing downwards between the interparietal sulcus and the occipital lobe to reach the middle of the inferior temporal or the lower border of the middle temporal convolution. In about half of all cases the area of the middle cerebral artery extends to the occipital pole, or half an inch anterior to it. It also supplies the tapetum of the corpus callosum and the white matter of the centrum semiovale corresponding to its cortical distribution. The cortical branches of the middle cerebral artery are the external orbital, the inferior external frontal, which supplies the inferior and middle frontal convolutions, the ascending frontal, which is distributed to the precentral convolution and the posterior part of the middle frontal convolution, the ascend-

ing parietal, which supplies the post-central convolution and the adjacent superior parietal lobule, the temporal branch, which supplies the superior and middle temporal convolutions, and the parieto-temporal branch, which continues the direction of the main stem of the artery and supplies the inferior parietal lobule, part of the lateral surface of the occipital lobe, and the posterior part of the temporal lobe

The Posterior Cerebral Artery. The two posterior cerebral arteries are the terminal branches of the basilar. They run backwards and upwards around the cerebral peduncles and beneath the splenium of the corpus callosum to the calcarine fissure of the occipital lobe. Close to its origin the posterior cerebral artery gives off basal branches which supply the posterior part of the optic thalamus, including the pulvinar, the posterior two-thirds of the crusta, and the red nucleus. Other branches pass around the brain-stem to supply the corpora quadrigemina and the geniculate bodies. The *posterior choroid arteries,* of which there are usually two, supply some branches to the optic thalamus, the brain-stem, and the third ventricle, and terminate in the choroid plexus of the third and lateral ventricles. There are four *cortical branches* of the posterior cerebral: the anterior temporal and the posterior temporal, which supply especially the uncinate gyrus, the calcarine branch, which passes along the calcarine fissure and is distributed to the visual area of the cerebral cortex, and the parieto-occipital branch, which passes along the corresponding fissure. The cortical area supplied by the posterior cerebral includes the median surface of the temporal lobe and of the occipital lobe as far forwards as the internal parieto-occipital fissure, or to a point one inch anterior to this The most anterior part of the temporal lobe, however, is supplied by the middle cerebral, and the anterior end of the uncinate gyrus including the uncus, by the anterior choroid artery The cortical area of the posterior cerebral extends on to the outer surface for a distance of from three-quarters to one inch, being here bounded by the posterior limits of the anterior and middle cerebral arteries. Above, it usually extends anteriorly as far as the external parieto-occipital fissure or in some cases to half-way along the superior parietal lobule; below, it supplies the medial aspect of the temporal lobe to within an inch of the tip.

Arteries of the Brain-stem.

The arteries of the brain-stem are mostly derived from the *basilar* and the two *vertebral arteries,* though the upper part of the midbrain receives in addition contributions from the posterior communicating artery, the anterior choroid artery, and the posterior cerebral and its branches. The vertebral arteries fuse at the level of the junction

between the pons and the medulla to form the *basilar artery*, which terminates at the upper border of the pons by dividing into the two posterior cerebrals. The arteries of the brain-stem show considerable variations of distribution, but conform on the whole to the following general scheme:

Paramedian arteries enter the brain-stem near the middle line anteriorly and supply a narrow zone extending from before backwards close to the middle line. Short circumferential arteries supply an area, often wedge-shaped, on the lateral aspect, and long circumferential arteries are distributed to the posterior part and to the cerebellum.

The Superior Cerebellar Artery is the highest branch derived from the basilar before its bifurcation. It passes outwards and backwards around the brain-stem, giving small branches to the cerebral peduncle and the corpora quadrigemina, and terminates by dividing to supply the upper surface of the vermis and of the lateral lobe of the cerebellum.

The Anterior Inferior Cerebellar Artery arises from the middle of the basilar and passes backwards to supply the anterior part of the lower surface of the lateral lobes of the cerebellum. *The Internal Auditory Artery* leaves the anterior inferior cerebellar artery or less often the basilar to accompany the acoustic nerve and enters the internal auditory meatus to supply the internal ear.

Throughout its length the basilar gives off small vessels to the anterior part of the pons.

The Lateral Artery of the Medulla is the lowest lateral branch of the basilar artery. It supplies a wedge-shaped area of the lateral aspect of the upper part of the medulla corresponding to the area supplied by the posterior inferior cerebellar artery in the lower part of the medulla.

The Posterior Inferior Cerebellar Artery is the largest branch of the vertebral. Its site of origin is variable, but it usually arises from this artery a little distance below the lower border of the pons. It then passes outwards and backwards around the medulla, giving branches which supply a wedge-shaped area of the lateral aspect of the medulla, the base of which is on the surface, and the apex postero-internally, and the lower part of the restiform body. It also supplies the choroid plexus of the fourth ventricle. The main trunk divides into two terminal branches which supply the inferior vermis and the lower surface of the cerebellar hemisphere.

The Vertebral Artery, besides supplying the lateral aspect of the medulla through the posterior inferior cerebellar, gives off branches to the paramedian region, a narrow zone adjacent to the middle line, including the pyramids of the medulla and extending backwards as

far as the floor of the fourth ventricle. This paramedian area at the lowest medullary level is supplied by the *Anterior Spinal Artery*, which arises by the fusion of a branch from each vertebral artery.

2 SYNDROMES OF THE CEREBRAL ARTERIES

Since the cerebral arteries are end-arteries their obstruction gives rise to a clinical picture which depends upon loss of function of the parts of the brain supplied by the vessel. This, of course, is influenced by the exact point at which the obstruction occurs, since blockage at the origin of a vessel leads to loss of function of a larger region than is the case when the obstruction is situated more distally or involves only a single branch. Variations in the clinical picture are also produced by the variability of the distribution of the arteries.

The Internal Carotid Artery.

Obstruction of the internal carotid artery, if it reaches the circle of Willis, causes blindness of the corresponding eye, with retinal ischaemia, hemiplegia, and loss of spatial and discriminative sensibility on the opposite side of the body, and, when the lesion is on the left side, aphasia, both receptive and expressive. If, however, the obstruction is too low to interfere with a collateral circulation through the circle of Willis, focal signs may be slight but mental confusion and, in the case of left-sided lesions, aphasia, may be the most prominent symptoms.

The Anterior Cerebral Artery.

This long vessel may undergo occlusion at a number of different points with a corresponding variety of symptoms. The following are the most important of these:

1 *Obstruction at its Origin, proximal to Heubner's Artery.* This causes hemiplegia on the opposite side together with sensory loss of the cortical type in the paralysed lower limb. When the lesion is on the left side there is in addition some mental deterioration, with verbal aphasia, and apraxia on the left, non-paralysed side. This last symptom is due to interruption in the corpus callosum of fibres running from the left supramarginal gyrus to the right precentral convolution.

2 *Obstruction of Heubner's Artery.* Since this artery supplies part of the frontal lobe, together with the anterior limb of the internal capsule, its obstruction leads to paralysis of the face, tongue, and upper limb on the opposite side, movements at the proximal joints of the limb being more affected than those at the distal joints. In addition, when the lesion is on the left side there is some mental deterioration and verbal aphasia.

3. *Obstruction distal to Heubner's Branch.* This leads to hemiplegia on the opposite side, the weakness being most marked in the lower limb. *In addition there is forced grasping and groping in the affected upper limb.*

4. *Obstruction of the Paracentral Artery.* This is the branch of the anterior cerebral artery which supplies the paracentral lobule containing the cortical centres for movements of the lower limb. The result of this lesion is a crural spastic monoplegia on the opposite side, with or without sensory loss of the cortical type in the affected lower limb.

The Middle Cerebral Artery.

Obstruction of the middle cerebral artery at its origin causes hemiplegia with sensory loss of the cortical type on the opposite side. The weakness is most marked in the face, tongue, and upper limb. When the lesion is on the left side there is also total verbal aphasia and an impairment of the comprehension of spoken and written speech. Obstruction of the inferior external frontal branch which is distributed to Broca's area causes total verbal aphasia with little or no weakness, *except possibly of the face and tongue on the opposite side.* Obstruction of the middle cerebral artery distal to this branch causes hemiplegia of the opposite side, the weakness being most marked in the upper limb, but speech disturbances are slight or absent. Obstruction of the parieto-temporal branch, when the lesion is on the left side, causes marked aphasia of the receptive type, with disturbance of comprehension of heard and written speech, with a speech disturbance of the type of jargon aphasia. In addition, there may be visual agnosia and a crossed homonymous defect of the visual fields, affecting principally or exclusively the upper quadrants.

The Posterior Cerebral Artery.

This artery supplies the visual cortex of the occipital lobe. Its occlusion, therefore, causes crossed homonymous hemianopia. The macular region of the blind fields usually escapes owing to overlapping of the posterior and middle cerebral areas of supply at the occipital pole.

The Basilar Artery.

Obstruction of the main trunk of the basilar artery is usually rapidly fatal. It leads to quadriplegia with sensory loss on both sides of the body. Unilateral obstruction of the paramedian branches of the basilar causes crossed hemiplegia of the Millard-Gubler or Foville type (see pp. 10–11). If the region deprived of its blood-supply extends backwards to involve the fillet there is loss of postural

sensibility on the paralysed side. Obstruction of one of the lateral branches of the basilar supplying the lateral region of the pons also leads to crossed hemiplegia of the Millard-Gubler or Foville type, with the addition of analgesia and thermo-anaesthesia on the opposite side, but without impairment of postural sensibility.

The Superior Cerebellar Artery.

Obstruction of the superior cerebellar artery causes unilateral symptoms of cerebellar deficiency on the side of the lesion, together with choreiform involuntary movements on the affected side. These are most conspicuous in the upper limb. There are also analgesia and thermo-anaesthesia on the opposite side of the body, since the superior cerebellar artery supplies a small lateral area of the pons containing the spino-bulbo-thalamic tract.

The Vertebral Artery.

The vertebral artery supplies the lateral region of the medulla by the posterior inferior cerebellar artery. Its paramedian branches supply the pyramidal tract, the fillet, and the nucleus and emerging fibres of the hypoglossal nerve. The same region of the medulla is supplied at its lowest level by the anterior spinal artery. Obstruction of the paramedian branches of either of these vessels on one side causes crossed hemiplegia with loss of postural sensibility, and paralysis of the tongue on the side of the lesion.

The Posterior Inferior Cerebellar Artery.

Thrombosis of this artery is not uncommon and leads to a characteristic clinical picture which results from infarction of a wedge-shaped area of the lateral aspect of the medulla. The onset of thrombosis is associated with severe vertigo, and vomiting may occur. There is dysphagia and, in some cases, pain or paraesthesiae, such as a sensation of hot water running over the face, may be referred to the trigeminal area on the affected side. There is some degree of cerebellar deficiency, with nystagmus, hypotonia, and inco-ordination on the side of the lesion. Ipsilateral paralysis of the soft palate, pharynx, and vocal cord results from involvement of the nucleus ambiguus. Horner's syndrome—myosis, enophthalmos, and ptosis—is present on the affected side. Dissociated sensory loss occurs, though its distribution is somewhat variable. Usually analgesia and thermo-anaesthesia are present on the face on the same side as the lesion and on the trunk and limbs on the opposite side. This is due to involvement of the spinal tract and nucleus of the trigeminal nerve and of the spino-thalamic tract respectively. The sensory loss on the face may be confined to the first, or to the first and second, divisions of

the nerve, since these regions are represented in the lowest part of the spinal nucleus, which may alone be supplied by the posterior inferior cerebellar artery. Persistent neuralgic pain in the face, on the side of the lesion, and sometimes in the limbs and trunk on the opposite side, is not uncommonly a troublesome sequel of this vascular lesion.

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3. INTRACRANIAL ANEURYSM

Definition: A localized dilatation of an intracranial vessel which may cause symptoms either through localized pressure upon neighbouring structures, especially cranial nerves, or by sudden rupture leading to subarachnoid haemorrhage.

1. Aneurysm of Congenital Origin

Aetiology and Pathology.

A congenital abnormality is the commonest cause of intracranial aneurysm.

'Congenital' aneurysms are due, as Turnbull (1914–15) and, more recently, Forbus (1930) have shown, to a deficiency in the media at the point of junction of two of the components of the circle of

Willis or at a bifurcation of one of the cerebral arteries. Though the aneurysm may itself be congenital it is probable that it may develop at any period of life on the basis of the congenital structural deficiency. 'Congenital' aneurysms may be single or multiple, as

FIG. 39 Congenital aneurysm of right posterior communicating artery compressing third nerve.

many as five having been described in the same individual. They are most frequently encountered on the intracranial course of the internal carotid artery, on the middle cerebral artery, and at the junction of the anterior communicating with the anterior cerebral arteries, but may occur on any superficial cerebral artery. They range in size from smaller than a pin's head to 30 mm. or more in diameter (Fig. 39). Microscopically the media is extremely narrow and fibrous and the elastic and muscular elements are absent. 'Congenital' intracranial aneurysms have occurred in more than

one member of the same family. They may be found at any age, but more than half first cause symptoms between the ages of 40 and 55 (Fearnsides 1916) and females suffer considerably more often than males. Sooner or later almost all these aneurysms rupture, and the extravasated blood may pass into the subarachnoid space, or into the substance of the brain, even reaching the ventricles. Rupture into the subdural space and even externally to the dura has been observed by Collier.

'Congenital' aneurysm often occurs in the absence of raised blood-pressure, though it is likely that a rise of blood-pressure in later life may be responsible, if not for the formation of the aneurysm, at least for its rupture.

Other congenital vascular abnormalities, such as aneurysm or defects of the media of abdominal arteries leading to intraperitoneal haemorrhage, coarctation of the aorta, and cutaneous naevi, have occasionally been observed in patients suffering from intracranial aneurysm.

Symptoms.

The symptoms of congenital intracranial aneurysm differ according to whether the patient is observed (1) before rupture, (2) immediately after rupture, or (3) after recovery from the immediate effects of rupture, and (4) radiography may show abnormalities

(1) Symptoms before Rupture of the Aneurysm

It is often impossible to diagnose an intracranial aneurysm before rupture occurs, since it may be too small to produce symptoms by compressing structures in its neighbourhood. However, if such symptoms occur, it is frequently possible to make a correct diagnosis. Unless the aneurysm is very large, symptoms of increased intracranial pressure do not occur at this stage. Headache, however, may be present, and the patient sometimes complains of tinnitus, while very rarely a pulsating systolic bruit is audible on auscultation of the skull. Apart from these variable symptoms the diagnosis of aneurysm rests upon evidence of focal pressure fairly sharply localized and only to a slight extent, if at all, progressive. The nature of such focal symptoms depends upon the situation of the aneurysm Aneurysms placed anteriorly in the circle of Willis may compress the optic nerve, leading to unilateral impairment of vision, which may be fluctuating and cause transitory attacks of blindness in one eye, superficially resembling migraine. In such cases optic atrophy and rarely slight papilloedema may be found in the affected eye and exophthalmos may be present. Hemianopia may result from compression of one optic tract or the chiasma may be compressed (Jefferson 1937, 1938).

Paralysis of the third, fourth, or sixth cranial nerves may occur with or without exophthalmos and pain, sometimes of sudden onset, or anaesthesia in the cutaneous area supplied by the first division of the trigeminal nerve. Aneurysms situated on the cortical course of the middle cerebral artery are likely to cause monoplegia or hemiplegia, and this is the only situation in which an aneurysm is likely to cause convulsions. Aneurysm of the posterior part of the circle of Willis, for example the posterior communicating artery, is likely to cause a paralysis of the third nerve and hemianopia due to compression of the optic tract. Aneurysm of the posterior cerebral artery may cause crossed hemianopia, owing to coincident thrombosis of the vessel. Aneurysm of the basilar artery usually causes conspicuous localizing signs early. There is often a crossed hemiplegia with paresis of some of the cranial nerves originating from the pons on one side, and of the limbs in the opposite side. A somewhat similar picture is produced by aneurysm of the vertebral artery which, however, is less common. Aneurysms of the cerebellar arteries rarely give rise to localizing signs.

(2) *Symptoms immediately following Rupture.*

Rupture of an aneurysm may prove rapidly fatal. In most cases, however, the patient survives, either to succumb in a few days or to make a more or less complete recovery, only to die from a subsequent leakage Effort is often a precipitating cause of the rupture.

The symptoms of rupture may be divided into (a) those due to rapidly increasing intracranial pressure with meningeal irritation, (b) focal symptoms, and (c) changes in the cerebro-spinal fluid.

(a) The intensity of the symptoms of increasing intracranial pressure varies according to the rapidity and persistence of the haemorrhage Loss of consciousness occurs rapidly when the leakage is considerable. Vomiting is not uncommon at the onset; convulsions are exceptional. When the patient is deeply comatose his breathing is usually irregular and his pulse slow. In less severe cases the patient may not lose consciousness completely, but may pass into a semi-stuporose state, lying in an attitude of general flexion, resenting interference, and confused and irritable when roused. Headache is severe, and the presence of blood in the subarachnoid space produces signs of meningeal irritation, such as cervical rigidity and Kernig's sign. Moderate pyrexia is common in this stage.

Changes are often found in the fundus oculi. Papilloedema is frequently present, though slight in amount. Retinal haemorrhages occur in some cases and may be accompanied by subhyaloid or vitreous haemorrhages which may be bilateral. These have been attributed to the passage of blood from the subarachnoid space of the

optic nerves into the eye, but it is more probable that the haemorrhages occur in the eye as the result of acute compression of the central vein of the retina by the blood in the optic sheaths Fundal changes may be absent when the leaking aneurysm is remote from the optic nerves.

Other signs of subarachnoid haemorrhage include diminution or loss of the tendon reflexes, and of the abdominal reflexes, and extensor plantar responses in the absence of gross muscular weakness. Albuminuria and glycosuria occasionally occur.

(b) *Focal symptoms* are due to compression of neighbouring cranial nerves by blood-clot or to invasion of the cerebral hemisphere by the haemorrhage. Visual field defects may occur as a result of compression of the optic nerves, chiasma, or tracts The third, fourth, and sixth cranial nerves are likely to be compressed if an aneurysm is near the cavernous sinus, while aneurysms springing from the posterior part of the circle of Willis may produce Weber's syndrome, paralysis of one third nerve, with 'crossed' hemiplegia, or Millard-Gubler's syndrome, facial paralysis with 'crossed' hemiplegia. Haemorrhage from an aneurysm at the junction of the anterior cerebral and anterior communicating arteries is apt to invade the frontal lobe and may cause mental impairment, hemiparesis, and, if on the left side, motor aphasia Leakage from an aneurysm on the cortical course of the middle cerebral may cause epileptiform convulsions and a monoplegia, while rupture of an aneurysm on the cortical course of the posterior cerebral may cause a crossed homonymous hemianopia as a result of haemorrhage into the substance of the occipital lobe or thrombosis of the artery. Leakage from an aneurysm of the basilar artery may lead to quadriplegia or to one of the various forms of 'crossed' paralysis , and head retraction is likely to be conspicuous when the haemorrhage is derived from an aneurysm in the posterior fossa. Herpes zoster is an occasional sequel of subarachnoid haemorrhage.

(c) *The Cerebro-spinal Fluid* Subarachnoid haemorrhage causes characteristic changes in the cerebro-spinal fluid, the pressure of which is raised at first In the first two or three days red cells are present, and the supernatant fluid exhibits a yellow coloration which persists for from two to three weeks. The protein content of the fluid is raised, though rarely above 0·1 per cent Irritation of the meninges by the extravasated blood leads to a pleocytosis consisting usually of mononuclear cells, though rarely polymorphonuclear cells may be present.

(3) *Symptoms persisting after recovery from Rupture.*

Recovery from the effects of rupture of an intracranial aneurysm may be remarkably complete, though headache is a common sequel.

Often, however, permanent damage is done by the haemorrhage and remains as evidence which may be misinterpreted if the patient is first seen some time after the rupture.

If intra-ocular haemorrhages have been severe recovery of vision may be incomplete, and defects of the visual fields may persist after haemorrhage in the region of the optic chiasma. There may also be some permanent weakness of cranial nerves which have been compressed. If the haemorrhage has invaded the cerebral hemisphere complete recovery from this lesion is not likely to occur. When the frontal lobe has been damaged there may be permanent mental changes which may even necessitate treatment at a mental hospital. Aphasia, hemiparesis, and hemianopia are also occasional sequels. Rarely troublesome root pains may remain as a result of irritation of the spinal roots by the extravasated blood.

(4) *Radiography.*

X-ray examination of the skull may demonstrate calcification in the wall of the aneurysm as a fine dense ring, or localized erosion of bone, e.g. of the clinoid processes on one side or enlargement of one optic foramen when the aneurysm is retro-orbital. Angiography with thorotrast may show its exact position.

Diagnosis.

If an aneurysm gives rise to symptoms before rupture it is most likely to be confused with intracranial neoplasm. Symptoms of increased intracranial pressure are rare, however, at this stage, and symptoms of focal pressure are usually strictly localized and very slowly progressive. Immediately after rupture the symptoms of meningeal irritation associated with pyrexia may simulate meningitis. This, however, is easily distinguished by lumbar puncture, which indicates the presence of subarachnoid haemorrhage. Intracranial aneurysm requires also to be distinguished from other conditions causing coma (see p. 303) and from other conditions in which subarachnoid haemorrhage occurs. This is occasionally found in exceptionally acute forms of encephalitis, but in such states the blood is likely to be present only in small amounts and there will be evidence of diffuse lesions of the nervous system. Traumatic subarachnoid haemorrhage is usually easily recognized through the history. Intracerebral haemorrhage due to vascular degeneration associated with high blood-pressure may reach the subarachnoid space either by rupture into the ventricular system, or, more rarely, to the surface of the brain. Such patients usually exhibit hemiplegia, which is rare in intracranial aneurysm, and a raised blood-pressure and arterial degeneration which are not necessarily associated with it. Moreover,

when subarachnoid haemorrhage is secondary to intracerebral bleeding the patient is more deeply comatose than is usually the case in ruptured intracranial aneurysm. Subarachnoid haemorrhage may occasionally be derived from a cerebral angioma, but this has usually previously yielded evidence of existence in the form of convulsions, hemiplegia, or signs of increased intracranial pressure, and may often be distinguished by the calcification within the tumour which is apparent in radiograms. Rupture of an embolic aneurysm may lead to a clinical picture indistinguishable from that which occurs when a congenital aneurysm is responsible for the haemorrhage. The former, however, is associated with progressive endocarditis or some other cause of chronic pyaemia, and its embolic origin is often associated with the sudden development of hemiplegia. Finally, spontaneous subarachnoid haemorrhage due to arterial degeneration without aneurysm formation may occur and may be suspected when angiography gives negative results.

Prognosis.

The prognosis of congenital intracranial aneurysm is always uncertain. Sooner or later 80 per cent of these aneurysms rupture. The first rupture may prove fatal or the patient may survive a series of such leakages, as many as five. One patient of the author's died at the age of 23, within eight hours of the first rupture; another had his first attack of subarachnoid haemorrhage at the age of 60 and made a good recovery from his fifth at the age of 70. There is a tendency for the interval between successive haemorrhages to become shorter. *The prognosis as to recovery from a given attack* of subarachnoid haemorrhage must be based upon evidence as to whether the haemorrhage has been arrested. Increasing depth of unconsciousness, rising pulse and respiratory rates, and increasing fever are bad signs, and prognosis is worse when the cerebral hemisphere has been invaded. If, after the haemorrhage appears to have stopped, the patient fails to show signs of improvement within forty-eight hours, the outlook is bad. Even after recovery from the immediate effects of rupture symptoms of damage done by the haemorrhage may persist, as described above.

Treatment.

If the diagnosis of intracranial aneurysm is made before rupture the patient must be enjoined to live a quiet life, as far as possible, and avoid any activity likely to raise the blood-pressure. The bowels should be regulated to prevent straining at stool.

After rupture has occurred lumbar puncture must be employed to reduce the raised intracranial pressure and to remove some of the

blood which is irritating the meninges. Lumbar puncture is not free from the risk that the withdrawal of cerebro-spinal fluid may cause a recurrence of the haemorrhage, but this risk must sometimes be taken. The fluid should, however, be allowed to escape only very slowly, and until the pressure is normal or until it runs at the rate of about one drop a second. Lumbar puncture should not be repeated at regular intervals, but only as the condition of the patient necessitates

The rectal administration of 8 oz. of 25 per cent. solution of magnesium sulphate is often helpful.

When the presence of an intracranial aneurysm is suspected an attempt should be made to localize it by angiography as soon as possible. Ligature of the afferent artery should always be considered, but carried out only with due precautions (Jefferson, 1937).

2. EMBOLIC INTRACRANIAL ANEURYSM

Embolic aneurysms are less than half as frequent as those of congenital origin and are rare after the age of 45. They are due to the impaction in a cerebral vessel of an embolus bearing organisms of low virulence. The aneurysm is the result of infective softening of the vessel wall. More virulent organisms usually cause cerebral abscess or meningitis. The embolus usually lodges in a cortical branch of one or other middle cerebral artery, the right and left being involved with equal frequency. Less often the main trunk of the middle cerebral artery or the anterior cerebral artery is affected. Embolic aneurysms elsewhere in the intracranial circulation are rare. Progressive endocarditis is the commonest cause of embolic aneurysm, which may, however, be a complication of other chronic forms of septicaemia and pyaemia. In most cases the aneurysm subsequently ruptures in the same manner as a congenital aneurysm.

The lodgement of the embolus is often the occasion of a 'stroke' and is followed by a hemiplegia or monoplegia. The signs of progressive endocarditis or of some other pyaemic source for the embolus are usually evident and emboli may occur elsewhere in the body. Rupture of an embolic aneurysm leads to subarachnoid haemorrhage, the symptoms of which are the same as those which follow rupture of a congenital aneurysm. Treatment of rupture is the same in both conditions, but the prognosis in embolic aneurysm is always grave, since even if the patient survives rupture of the aneurysm the causal pyaemic condition usually proves fatal.

3. CAROTID-CAVERNOUS SINUS ANEURYSM

Arteriovenous aneurysm produced by rupture of the internal carotid artery into the cavernous sinus may arise spontaneously or

may follow head injury with or without fracture of the skull. It is probable that in traumatic cases there is often a pre-existing aneurysm of the internal carotid which ruptures into the sinus. The resulting clinical picture is highly distinctive, consisting of unilateral pulsating exophthalmos, with oedema of the eyelids, conjunctivae, and cornea, and sometimes papilloedema. There is a loud systolic murmur, audible to the patient and on auscultation over the temporal region or even over the whole skull, and suppressible by compression of the ipsilateral carotid artery. There is complete or partial ophthalmoplegia of the affected eye. The other eye may become involved, blood at arterial pressure being carried by the circular sinus to the opposite cavernous sinus. Ligature of the corresponding carotid artery has been successful in diminishing the symptoms in some cases, but is not without risk of leaving a residual hemiplegia.

4. OTHER CAUSES OF INTRACRANIAL ANEURYSM

Other causes of intracranial aneurysm are extremely rare, though examples undoubtedly due to periarteritis nodosa, to atheroma and to syphilis have occasionally been described. The characteristic syphilitic change of the small elastic and muscular arteries, to which group the intracranial vessels belong, is an obliterative endarteritis, *a fact which probably explains the rarity of syphilitic intracranial aneurysm.* Most of the verified syphilitic aneurysms have been situated upon the basilar artery, which, as Fearnsides suggests, is, on account of its size, less likely to be obliterated by intimal proliferation and more likely to develop local weakening of its wall than the smaller intracranial vessels. If there is reason to suspect that an intracranial aneurysm may be caused by atheroma or syphilis, the proper treatment for these conditions should be carried out.

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4. CEREBRAL ARTERIOSCLEROSIS

Aetiology and Pathology.

The term 'cerebral arteriosclerosis' is usually limited to degenerative changes in the arteries of the brain. Strictly interpreted, however, as arterial thickening it occurs also in inflammatory conditions. The following are the most important causes of arteriosclerosis: (1) *Primary degeneration of the intima.* This takes the form of atheroma. There is degeneration of the intima with the production of fat debris and some reactionary fibrosis. Calcification may occur in the degenerated area. There is usually some medial degeneration. The causes of primary atheroma are little understood. It occurs principally in late middle age and old age, yet some very old individuals may show little or none. Metabolic diseases, such as diabetes, also cause atheroma. (2) *Degeneration secondary to high blood-pressure.* High blood-pressure is associated with hypertrophy of the media of the arteries and the hypertrophied media undergoes degeneration. Atheroma occurs partly as a result of medial degeneration and partly as the effect of the raised blood-pressure itself. (3) *Endarteritis* causes thickening, especially of the intima. The only common cause of cerebral endarteritis is syphilis. This condition is therefore more fully described in the section on syphilis of the nervous system. (4) *Thrombo-angeitis obliterans* is an inflammatory disease affecting all the coats of the blood-vessels and leading to thrombosis and fibrous occlusion of the lumen. The disease is generalized throughout the blood-vessels, but cerebral symptoms, though they occasionally occur, are rare. (5) *Periarteritis nodosa* is also a rare cause.

The effect of progressive occlusion of the cerebral blood-vessels is an impairment of circulation in the regions they supply. As a result of this, impairment of cerebral function occurs before any vessel

is completely blocked. At this stage a patchy degeneration of cortical cells and of nerve-tracts, leading to disseminated areas of atrophy, is found. Actual obstruction of arteries by atheroma, with or without subsequent thrombosis, causes softening of the region of the brain supplied by the vessel. These areas of softening may be large or small, single or multiple. In the early stages the softened patch is white or red and later becomes yellow. The nerve-cells in the necrotic area degenerate, and in the surrounding tissues there is neuroglial overgrowth with infiltration, especially by compound granular corpuscles The late result is a neuroglial scar or a cystic cavity.

Degenerative cerebral arteriosclerosis is chiefly a disease of late middle life and old age, though it may be encountered much earlier, even at the age of 40 The sexes are equally affected, and it is not uncommon to meet with a familial predisposition.

Symptoms.

Progressive cerebral ischaemia due to arteriosclerosis leads to impairment of cerebral function before actual blockage of vessels occurs The course of the disease is complicated, however, by the occurrence of small or large areas of cerebral softening due usually to cerebral thrombosis

The onset of the disease is often insidious and its course slowly progressive, or there may be apoplectiform attacks of varying severity leaving residual focal symptoms. The symptoms differ also according to the part of the brain mainly affected. Thus mental symptoms may overshadow motor disturbances, or vice versa, or both may be combined.

Mental symptoms in milder cases consist of a general reduction in intellectual capacity with impairment of memory, especially for recent events, and emotional instability. There is a marked tendency to reminiscence and confabulation may occur The patient becomes self-centred and hostile to change in all forms. In more severe cases loosely constructed delusions occur and there is often a paranoid trend. Depression is not uncommon and there may be attacks of confusion, which are apt to be precipitated by removal from home and by operations, for example, for cataract or for removal of the prostate. Still greater deterioration leads to a profound dementia (see p. 900).

Epileptiform attacks are common and may take the form either of petit mal, of Jacksonian or uncinate attacks, or of generalized epileptic fits. Various forms of aphasia and apraxia are met with Pyramidal lesions may take the form of monoplegia, hemiplegia, or double hemiplegia leading to one variety of pseudo-bulbar palsy. Paraplegia of cerebral origin may occur. The grasp reflex may be

encountered in one or both hands and feet, with or without slight pyramidal involvement. Senile tremor is common and athetosis may occur. Generalized chorea is exceptional, but unilateral chorea due to softening in the region of the hypothalamic nucleus is less uncommon. Arteriosclerotic Parkinsonism is also seen (see p. 518). Cerebellar syndromes are sometimes met with. Visual impairment is common as a result of retinitis or retinal venous thrombosis or thrombosis of the central retinal artery. Less frequently it is due to softening involving the optic radiations or visual cortex, and I have seen complete blindness produced by bilateral occipital softening. General arteriosclerosis is usually well marked. The blood-pressure is high in the hyperpietic group, but little, if at all, raised in patients with the decrescent type of arteriosclerosis.

Diagnosis.

Cerebral arteriosclerosis may simulate *intracranial tumour*. Its course, however, is more fluctuating and interrupted by apoplectiform incidents. There is usually evidence of multiple lesions and of arteriosclerosis in other parts of the body. When, however, arteriosclerosis finds expression in a progressive focal lesion associated, as is sometimes the case, with papilloedema, the diagnosis from tumour may be extremely difficult and ventriculography may be necessary. *General paralysis* usually develops at a much earlier age than cerebral arteriosclerosis, which, however, it may simulate either on account of the mental deterioration or because of the occurrence of congestive attacks leading to hemiplegia. The presence of Argyll Robertson pupils and of a positive Wassermann reaction in the blood and cerebro-spinal fluid renders the diagnosis easy. *Alzheimer's disease* also begins at an earlier age than most cases of cerebral arteriosclerosis The dementia is more profound in the former than is usually the case in the latter. The early signs do not include pyramidal lesions and evidence of general arteriosclerosis is usually lacking. *Pick's disease* coincides with cerebral arteriosclerosis in its age incidence Mental changes ending in dementia and speech disturbances are more prominent in the former, while signs of pyramidal lesions and of general arteriosclerosis are usually lacking. (See also pp 902-3)

Prognosis.

The general course of cerebral arteriosclerosis is a progressive deterioration. Cases vary greatly, however, according to the situation of the principal lesions. The downward course may be accelerated by focal disturbances such as hemiplegia. On the other hand, there is often a considerable degree of recovery from these episodes. For

example, a patient suffering from cerebral arteriosclerosis may pass into a confusional state necessitating certification, and after a period of weeks or months may make a good recovery. The course of the disease is measured in years, and in the terminal state the patient is bedridden, with a variable degree of dementia, with or without hemiplegia, pseudo-bulbar palsy, arteriosclerotic Parkinsonism or similar physical concomitants. Death occurs in coma from cerebral thrombosis or from simple inanition or from some intercurrent disease, such as broncho-pneumonia or urinary infection.

Treatment.

Treatment is mainly symptomatic, since little can be done to arrest the deterioration of the blood-vessels. The patient must lead a quiet life, avoiding both mental and physical exertion. Potassium iodide is the most useful drug and may be given in conjunction with small doses of thyroid extract. Epileptiform attacks are usually well controlled by phenobarbital and the bromides, and these drugs are also *useful in the treatment of insomnia and of mental excitability.* Focal symptoms will require appropriate treatment.

5. CEREBRAL HAEMORRHAGE

Aetiology and Pathology.

Intracranial haemorrhage may be venous, capillary, or arterial. Little is known about intracranial venous haemorrhage, but it has been regarded as the cause of acute cerebral lesions during whooping cough and may occasionally occur in other circumstances. Capillary or petechial haemorrhages are found in a variety of toxic and infective conditions, for example in salvarsan poisoning, in acute inflammatory states, such as the various forms of acute encephalitis, in septicaemia, and in any form of severe anaemia and in thrombo cytopenic purpura. Haemorrhage may occur into a cerebral tumour, for example a glioma, or one of the vessels composing an angioma may bleed, either into the substance of the brain or into the subarachnoid space. Severe trauma, especially if it involves fracture of the *skull or penetration of the brain by a missile, is likely to cause* haemorrhage, which may be either venous, capillary, or arterial.

Arterial haemorrhage may be extradural, subdural, subarachnoid, or intracerebral. The first three are described elsewhere. The commonest cause of intracerebral arterial haemorrhage is rupture of an atheromatous artery *in an individual suffering from* high blood-pressure. The rise in blood-pressure is usually due to primary hyperpiesia, much less frequently to chronic nephritis or congenital

cystic kidney. The arterial degeneration is closely bound up with the rise of blood-pressure. According to Turnbull, the first change in the arteries in this condition is hypertrophy of the media. The hypertrophied media undergoes degeneration, and atheroma of the intima occurs as a result, partly of the raised pressure and partly of the degeneration The result is a thickened but brittle vessel. Miliary aneurysms have often been described on the cerebral vessels in arteriosclerosis, but their existence is doubted by some modern authorities.

There are thus two factors in the causation of arterial cerebral haemorrhage, the degeneration of the vessel and the raised blood-pressure. The former in the absence of the latter is likely to lead to thrombosis rather than haemorrhage, while haemorrhage does not necessarily occur even when the blood-pressure is very high, unless vascular hypertrophy has given place to degeneration. This account, however, probably is too simple and there are other unknown factors (Stern, 1938) Moreover, cerebral haemorrhage occasionally occurs in the absence of high blood-pressure probably as a result of developmental vascular abnormalities (Elkington, 1935).

Most cases of cerebral haemorrhage are found in late middle life. It is comparatively rare in younger hyperpietics and the vascular changes of old age more often lead to thrombosis and cerebral softening Males are more frequently affected than females. A familial incidence is common.

Cerebral haemorrhage may occur in any situation, but it is especially common in the region of the internal capsule and pons. The blood-clot may remain encapsulated in the brain or may burst into one lateral ventricle, or, much less frequently, superficially into the subarachnoid space.

After a large intracerebral haemorrhage the affected hemisphere is larger than the opposite one and the convolutions are flattened. The site of haemorrhage is occupied by a red clot and the surrounding tissues are compressed and may be oedematous. Later the clot is absorbed and may be replaced by a neuroglial scar or by a cavity containing a yellow serous fluid. During absorption of the clot ghosis takes place in the walls of the cavity with phagocytosis of destroyed neural tissue by compound granular corpuscles. Multiple haemorrhages are not uncommon.

Symptoms.

The occurrence of cerebral haemorrhage is always sudden, but the patient may be known to have a high blood-pressure and there may have been premonitory symptoms, such as transitory speech disturbances or attacks of weakness of a limb. The actual rupture of the

These movements do not occur on the paralysed side. The absence of such movements, however, may also be due to hemianalgesia. This may often be demonstrated by the fact that reflex contraction of the facial muscles occurs when the patient is pricked on one side of the body, the normal side, but not when he is pricked on the analgesic side. The tendon reflexes are variable. They may be much diminished or abolished on the paralysed side; sometimes they are exaggerated. The plantar reflex on the affected side is extensor; on the normal side it may be flexor or extensor. The abdominal reflexes are often lost on both sides in coma. Retention or incontinence of urine and faeces are the rule as long as the patient is unconscious.

Pontine Haemorrhage.

If the patient is seen soon after the onset of the haemorrhage, the signs may be those of a unilateral lesion of the pons, namely, facial paralysis on the side of the lesion with flaccid paralysis of the limbs on the opposite side. Owing to paralysis of conjugate ocular deviation and of rotation of the head to the side of the lesion the patient lies with his head and eyes turned towards the side of the paralysed limbs. Even when the signs at the outset are those of a unilateral lesion of the pons, extension of the haemorrhage soon involves the opposite side, or the signs may be bilateral from the beginning. When both sides of the pons are thus affected there is paralysis of the face and limbs on both sides, with bilateral extensor plantar reflexes. Marked contraction of the pupils, 'pinpoint pupils', the result of bilateral destruction of the ocular sympathetic fibres, is characteristic of a pontine haemorrhage. Moreover, destruction of the pons cuts off the body from the control of the heat-regulating centres in the hypothalamus, and the patient becomes poikilothermic. Since much care is usually taken to keep an unconscious patient warm, his temperature gradually rises and may reach a high level.

Haemorrhage into the Ventricles.

It is not uncommon for a haemorrhage in the region of the internal capsule to burst into the lateral ventricle. If the patient is not seen until after this has occurred it may be difficult to differentiate intra-ventricular from pontine haemorrhage. After ventricular haemorrhage coma deepens and signs of a pyramidal lesion are usually present on both sides of the body. There is often a tendency for the upper limbs to adopt a posture of rigid extension. The temperature frequently exhibits a terminal rise, also seen in pontine haemorrhage.

The symptoms of cerebral haemorrhage in other situations are those of a massive focal lesion and are similar to the focal symptoms of a tumour in the same region (see p. 244).

The cerebro-spinal fluid after cerebral haemorrhage is under increased pressure and its protein content may be somewhat raised. The presence of blood in the fluid indicates usually that the haemorrhage has ruptured into the ventricular system, less frequently that it has come to the surface of the brain and ruptured into the subarachnoid space. The heart is usually enlarged and the blood-pressure raised and the superficial arteries may be thickened and tortuous. Albuminuria may be present, and glycosuria is a not uncommon result of the cerebral lesion.

Diagnosis.

Since in the early stages of cerebral haemorrhage the patient is usually comatose, it is necessary to differentiate this from other causes of coma.

In *cerebral thrombosis* the onset is usually much more gradual than in cerebral haemorrhage, and the symptoms may increase in severity for twenty-four or even forty-eight hours. Unconsciousness is less common and when it occurs usually less profound. The blood-pressure is less frequently raised, and there may be evidence of pre-existing disease leading to vascular damage, for example, syphilis or diabetes.

The onset of *cerebral embolism* is more sudden even than that of haemorrhage, though after the onset the symptoms may increase in severity owing to the development of cerebral oedema or of thrombosis in the affected vessel. Unconsciousness occurs less frequently than in haemorrhage, and the source of the embolus is usually discoverable.

Subarachnoid haemorrhage from ruptured intracranial aneurysm usually occurs at an earlier age than intracerebral haemorrhage. Signs of meningeal irritation are prominent, and focal signs of destruction of cerebral tissue are usually, though not always, absent. Blood is found in the cerebro-spinal fluid, and, though this may occur in intracerebral haemorrhage, in the latter condition hemiplegia is usually present in such cases and coma is more profound than is usual in subarachnoid haemorrhage.

Coma, when it develops in a case of *intracranial tumour*, usually does so gradually, though haemorrhage into a tumour may cause rapid loss of consciousness. A history of symptoms of increased intracranial pressure, especially headache, is usually obtainable and papilloedema is likely to be present. Signs of vascular disease are usually absent, and diagnosis may be extremely difficult when a tumour develops late in life in a patient who also suffers from hyperpiesia.

When *head injury* is the cause of coma there is usually a history of

injury and there may be bruising of the scalp or signs of fracture of the base of the skull, such as bleeding from the ear or bleeding or discharge of cerebro-spinal fluid from the nose. It must be remembered, however, that a patient who becomes unconscious from some other cause may *injure his head in falling*. In slighter cases of head injury complete unconsciousness is usually brief and is followed by a stage of 'traumatic delirium' in which the patient is confused, complains of headache and photophobia, and lies curled up in bed resenting interference. Traumatic intracranial arterial haemorrhage leads to progressively deepening coma with signs of a focal lesion of one hemisphere, often beginning with convulsions and leading to hemiplegia The unconsciousness due to concussion may pass without interruption into that due to haemorrhage, or there may be a lucid interval in which consciousness is recovered and the patient is apparently normal. This interval may last for several hours before unconsciousness again develops. Subdural haematoma is a late result of head injury liable to develop, especially in the elderly, weeks or even months after an accident. It is characterized by headache and ultimately unconsciousness, which often fluctuates in depth. Papilloedema and signs of focal cerebral compression are often present but may be absent.

In a case of *post-epileptic coma* there is usually a history of epilepsy or at least of the fit which preceded the coma. In the absence of this information scars on the face or a bitten tongue may provide a clue. Focal signs of a cerebral lesion are absent, but the plantar reflexes may be extensor. After a single fit the period of unconsciousness is usually short, not more than half an hour, but status epilepticus may be followed by prolonged coma.

In *diabetic coma* the patient is usually wasted and pale. Both the rate and amplitude of the respirations are much increased and the ocular tension is very low. The reaction of the pupils to light may be lost even while the patient can still be roused. Large quantities of sugar are demonstrable, together with diacetic acid and acetone, in the urine, and the blood-sugar is much raised.

Hypoglycaemic coma is easily recognized if it is due to an overdose of insulin which the patient is known to be taking. Occasionally, however, persistent hypoglycaemia occurs as a result of excessive production of insulin by a tumour composed of cells of the islands of Langerhans of the pancreas. In such cases fainting fits or convulsions may precede the onset of coma. The diagnosis can only be made by an examination of the blood-sugar, which is found to be extremely low This investigation, therefore, should always be carried out in cases of coma, the cause of which is obscure.

Hypertensive encephalopathy may lead to coma in acute nephritis,

eclampsia, and malignant hypertension. Convulsions and headache are common, and papilloedema with or without oedema of the retina is found. Transient cerebral symptoms including blindness, aphasia, and hemiplegia may occur and are associated with raised blood-pressure. The retinal changes, convulsions, and fluctuations in the symptoms are the distinctive features.

Uraemic coma may occur in chronic nephritis and other conditions causing renal destruction. In chronic nephritis, headache, vomiting, dyspnoea, and muscular twitchings or generalized convulsions precede coma. Cardiovascular hypertrophy is present and the blood-pressure is raised. Albuminuric retinitis is common. Albuminuria is inconstant, but the specific gravity of the urine is usually low. Urea excretion is much impaired, and the urea content of the blood and cerebro-spinal fluid is greatly raised and usually lies between 100 and 500 mg. per 100 c cm.

Acute alcoholic coma follows the milder symptoms of alcoholic intoxication. The patient, though unconscious, can usually be roused to some extent. The pulse is full and the respirations in the earlier stages deep. The pupils are usually dilated and react to light, though this reaction may be lost if the coma is very profound. Alcohol can be smelt in the breath and demonstrated by chemical tests in the urine, but it must be remembered that alcohol may be given to a patient who is becoming comatose from some other cause and also that an intoxicated individual may fall and sustain a head injury. Evidence that the patient has taken alcohol does not necessarily mean that his unconsciousness is due to alcoholic poisoning.

Opium Poisoning. In coma due to opium poisoning the patient is pale and often cyanosed. The skin is cold and the temperature subnormal. Respirations are slow and feeble. The pupils are much contracted and fail to react to light.

In poisoning with *other sedative drugs*, such as chloral, sulphonal, barbital, and pheno-barbital, the picture resembles opium poisoning, except that the respiratory rate is often raised and the depth of respiration increased and the pupils are usually moderately dilated and react to light either sluggishly or not at all. Haematoporphyrinuria may be present in sulphonal poisoning.

In *hysterical trance* the patient, though apparently unconscious, usually shows some response to external stimuli. An attempt to elicit the corneal reflex often causes a vigorous contraction of the orbicularis oculi. Rigidity of the hysterical type is often present and any attempt passively to overcome the rigidity excites a proportional increase in the stiffness which resists the observer's efforts. Signs of organic disease in the nervous system are absent.

Hypersomnia due to a lesion of the hypothalamus is distinguished

by the fact that the patient can be roused and is then temporarily relatively normal, the condition resembling profound sleep.

Coma in *acute encephalitis and meningitis* is usually easy to diagnose. It usually occurs in children and young adults and is preceded by the symptoms of acute inflammation of the brain or its membranes, signs of which are found on examination. Characteristic changes are usually found in the cerebro-spinal fluid.

The 'congestive attacks' of *general paralysis* may simulate cerebral haemorrhage closely owing to the rapid onset of hemiplegia with loss of consciousness. Other signs of general paralysis, especially Argyll Robertson pupils, are usually present, and examination of the cerebro-spinal fluid and the blood Wassermann reaction settles the diagnosis.

Prognosis.

The immediate problem in the case of cerebral haemorrhage is whether or not the haemorrhage will prove fatal. Death may occur from medullary anaemia as a result of continuance of the bleeding. Even if the bleeding stops, the destruction of brain-tissue and rise of intracranial pressure may cause the patient to remain unconscious so long that adequate feeding is impossible and he dies of exhaustion or from an intercurrent infection, such as pneumonia. When haemorrhage continues death may occur rapidly, though rarely in less than a few hours, usually during the first two days. The patient may linger in a comatose condition for as long as a week. If the haemorrhage is continuing there is a progressive deepening of the coma, indicated by inability to rouse a formerly responsive patient and loss of the corneal and pupillary reflexes; the pulse tends to become rapid and irregular; the respiratory rate is often irregular and finally becomes rapid and shallow, and both the temperature and the blood-pressure tend to rise.

Bilateral paralysis of limbs is a sign of bad prognostic import, because it indicates either ventricular or pontine haemorrhage, both of which are usually fatal. A haemorrhagic cerebro-spinal fluid usually means a ventricular haemorrhage. If the patient shows no signs of recovery from coma forty-eight hours after the onset of the haemorrhage the chances of recovery are poor, even though the haemorrhage may have stopped.

When the patient recovers consciousness he is naturally anxious to know whether he is likely to suffer from permanent disability. This depends upon the situation of the haemorrhage and the extent of the resulting destruction of brain-tissue. It must be remembered that neural shock and oedema of surrounding areas of brain usually cause a more severe depression of function than is actually due to the destructive effect of the lesion. Some improvement may therefore be

*expected in most cases. The mental efficiency of the patient is rarely
as good after a cerebral haemorrhage as before. Apart from lesions
grossly impairing functions of intelligence and speech there is usually
diminished power of concentration and memory, together with irrita-
bility and emotional instability.*

Haemorrhage in the region of the posterior part of the third frontal
convolution on the left side may cause for a time total aphasia, but
in these cases a very considerable recovery of speech usually occurs
in time, and *improvement may continue for many months* The
speech defect which follows a capsular haemorrhage is a dysarthria
and usually improves rapidly. Damage to the pyramidal tract by
a haemorrhage in the region of the internal capsule causes spastic
hemiplegia on the opposite side, the signs of which are described
elsewhere (see p. 6). Some return of power always occurs in the
lower limb, so that the patient is likely to be able to walk If the
upper limb exhibits returning power at the end of a month after
the onset a considerable degree of recovery will probably occur in it
If, however, there is no improvement at the end of three months
the paralysis is likely to be permanent When the posterior part of the
capsule is involved, sensory loss and homonymous hemianopia on the
side opposite to the lesion may be added to the paralysis Improve-
ment may occur in respect of these disorders, but is often incomplete
Pain on the paralysed side of the body is not uncommon after a
capsular haemorrhage and is of thalamic origin If it develops it is
likely to be persistent. Involuntary movements sometimes occur
after cerebral haemorrhage, but only when paralysis of the limbs
is incomplete They usually appear several weeks or months after
the onset, with the return of voluntary power, and are always more
marked in the upper than in the lower limb Simple tremor may
develop and is most evident on voluntary movement. Less often there
is tremor of the Parkinsonian type which occurs when the limb is at
rest. Athetosis also is sometimes seen. All these movements tend to
be persistent, though some improvement may occur, especially in the
tremor. They are probably due to involvement of the corpus stria-
tum. Choreiform movements may occur as a result of haemorrhage in
the region of the hypothalamic nucleus Such cases often end fatally,
though improvement and even recovery may take place. Trophic
changes are common in the paralysed limbs. There is often cyanosis
of the extremities and oedema is not rare The nails may be brittle.
Arthritis of the larger joints is seen, especially in senile patients.

Treatment.

Continuing cerebral haemorrhage causes death from medullary
anaemia. The objects of treatment are, therefore, to stop the haemor-

rhage and to reduce the intracranial pressure. The patient should be moved as little as possible, and care should be taken that there is no hindrance to venous return from the head. An ice-bag applied to the scalp can do no harm and may diminish the cerebral blood flow.

Surgical evacuation of the clot is a rational procedure but is rarely practicable. It should, however, be considered when cerebral haemorrhage occurs before middle life, in view of the possibility of haemorrhage into an intracranial tumour.

Venesection, the withdrawal of a pint of blood from a vein, is a time-honoured method of treatment. It has been argued that it is contra-indicated as likely to add to the risk of medullary anaemia. It is probable that it does good, however, by lowering the intra-cranial pressure, and it possesses definite value especially in plethoric individuals. Lumbar puncture has been advocated as the most direct and harmless method of lowering the intracranial pressure, but is not free from risk, since the withdrawal of a considerable quantity of cerebro-spinal fluid from the spinal theca is likely to cause a shift in the cranial contents which may both increase the haemorrhage and lead to compression of the medulla in the foramen magnum. Compression of the internal carotid artery on the side of the haemorrhage has been recommended to promote clotting, but when a considerable area of the hemisphere has been rendered anaemic by the compression exerted by the haemorrhage any further impairment of blood-supply would seem to involve the risk of adding to the permanent loss of function.

A purgative should be administered as soon as possible after the onset, and when the patient is unconscious may take the form of 1 minim of croton oil in a little butter. The rectal injection of 8 oz. of a 25 per cent. solution of magnesium sulphate helps to lower the intracranial pressure. If the patient is profoundly unconscious he ceases to swallow, and other methods of feeding must be employed. Fluid can be given in the form of normal saline by the rectum, and if necessary concentrated liquid nourishment can be administered by a nasal tube. Regular catheterization may be necessary, and the action of the aperient should be assisted with enemas. The skin must be carefully looked after and the risk of burns from exposure to hot-water bottles borne in mind.

After recovery from the immediate effects of the haemorrhage the patient must be encouraged to make an attempt to use his paralysed limbs. Massage and passive movements may help to diminish spasticity, but electrical treatment is of no value. If the toe drags in walking this may be counteracted by wearing a special boot with a spring attached below to the toe and above to a gaiter round the calf.

6. THROMBOSIS OF THE CEREBRAL ARTERIES

Aetiology and Pathology.

The causes of thrombosis of the cerebral arteries are—disease of the arteries, leading to reduction of their lumen and thickening of the intima; abnormalities of the blood causing increased coagulability, and factors which produce a general reduction in the circulatory rate. More than one of these disturbances is often present in the same individual. We find, therefore, that cerebral thrombosis may occur as a result of any of the forms of cerebral arteriosclerosis described in section 4. In early middle life syphilitic endarteritis is the commonest cause, in late middle life and old age atheroma of the cerebral arteries. Thrombo-angeitis obliterans is a rare cause. Cerebral thrombosis may also occur in acute infections, for example, diphtheria and typhoid fever, which both damage the arteries and impair the efficiency of the circulation. Small thrombi are common in acute infections of the nervous system, for example, the various forms of encephalitis. Any profound anaemia may cause cerebral thrombosis, which may also be produced by the reverse condition—erythraemia. Pregnancy is also an occasional cause, though how it operates is obscure. Given thickening of a cerebral artery from any cause, thrombosis is more likely to occur when the blood-pressure is low than when it is high. Hence the senile myocardial changes associated with generalized atheroma play a part in producing thrombosis by impairing circulatory efficiency. The lodgement of an embolus in a cerebral artery is followed by thrombosis distal to the block, and if the clot also extends proximally it may cause an extension of the symptoms resulting from the embolism. The end result of obstruction of a cerebral artery is infarction, with softening of the region of brain supplied by the vessel (see p 284)

Symptoms.

When cerebral thrombosis develops in a patient with cerebral arteriosclerosis he has not uncommonly had prodromal symptoms, for example, transitory attacks of aphasia, mental confusion, paresis, or paraesthesiae Although the hypothesis of vascular spasm as an explanation of these symptoms is somewhat discredited, it is probable that they represent a transitory increase in the degree of impairment of the blood-supply to part of the brain The onset of the thrombosis itself is usually gradual and the resulting symptoms may not reach their height for one or two days. Headache and giddiness are usually present and vomiting may occur. Loss of consciousness is inconstant and not as a rule profound. The patient may be merely dazed and

confused. Unconsciousness is more likely to occur when the thrombosis involves part of one hemisphere than when it is situated in the brain-stem, and when the patient is elderly and has considerable general cerebral arteriosclerosis. In such cases it tends to develop gradually some time after the beginning of the focal symptoms. Convulsions are not very common, but occur more frequently than in cerebral haemorrhage. The focal symptoms of cerebral thrombosis depend upon the vessel affected (see section on Syndromes of the Cerebral Arteries, p. 284).

Diagnosis.

See diagnosis of Cerebral Haemorrhage, p. 303.

Prognosis.

The immediate prognosis in cerebral thrombosis depends upon the size of the vessel obstructed and the general condition of the patient. Thrombosis of the internal carotid and of the main trunk of the basilar artery is usually fatal, but the patient may survive thrombosis of other arteries, though in old and debilitated subjects with widespread arteriosclerosis a comparatively small area of cerebral softening may prove fatal. After recovery from one attack, unless the underlying cause can be remedied, further attacks may occur, and it is not uncommon for a series of attacks of thrombosis to follow one another at short intervals. These are probably the result of a fall of blood-pressure due to the patient being kept in bed on account of the first attack. When the outcome is favourable some improvement in the symptoms usually begins after a few days owing to diminution in shock and reduction of oedema in the infarcted area. Some residual symptoms usually remain as a result of permanent destruction of nerve-tissue, and the nature of this depends upon the part of the brain involved. Epileptic attacks may occur as a sequel of cerebral thrombosis

Treatment.

The main object of treatment is to improve the circulation in order, if possible, to prevent extension of the thrombus.

When the patient is unconscious, nursing and feeding must be carried out as in the case of cerebral haemorrhage. All depletive measures, such as venesection, purgation, and treatment with hypertonic solutions, are to be avoided. Heparin may be given to diminish the coagulability of the blood. Strychnine may be given subcutaneously and digitalis may improve the heart's action. Iodides may help to combat atheroma and promote absorption of exudate. Phenobarbital and bromide are useful for the treatment of restless-

ness, and aspirin and pyramidon may be required for the relief of headache. The patient should be got out of bed at the earliest opportunity Focal symptoms will require appropriate treatment, and any general disease, for example diabetes or syphilis, which may be responsible for the thrombosis will need to be treated

7. CEREBRAL EMBOLISM

Aetiology and Pathology.

Embolism of a cerebral artery is a complication of a large variety of disorders which possess in common the opportunity for blood-clot, or, less frequently, other material, to enter the circulation in such a way that it can reach the brain Retracing the circulation backwards from the brain we find that the nearest source of a thrombus is the right subclavian artery. In rare cases of thrombosis of the right subclavian artery due to pressure by a cervical rib, the thrombus has extended into the right common carotid and a detached portion has been carried into the brain (Symonds). A clot may come also from an aneurysm of the innominate artery or of the aorta or from an atheromatous ulcer in this vessel. A vegetation may become detached from the aortic valves in progressive endocarditis. The left ventricle may be the source of an embolus, following coronary thrombosis, when a clot forms on the endocardium over the infarcted area or when aneurysm of the ventricle results Vegetations may be detached from the mitral valve in progressive endocarditis, or a clot may form in the left auricle in mitral stenosis of rheumatic origin This is most likely to occur in auricular fibrillation, and in such cases detachment of the clot may follow the restoration of the normal cardiac rhythm by means of quinidine It may also occur in auricular flutter. The source of the thrombus may be in the lung, when thrombosis of a pulmonary vein occurs Infected emboli from the lungs are the cause of cerebral abscess complicating pulmonary infection, and tumour cells may pass in the same way from the lung to the brain The lung capillaries constitute a filter which protects the general circulation from emboli of any size derived from the systemic veins. Fat globules, however, may pass through the pulmonary circulation and so reach the brain after fracture of one of the long bones. A patent interventricular septum short-circuits the pulmonary capillary filter and provides a route by which emboli from the systemic veins can in exceptional circumstances reach the brain—*paradoxical embolism* I have twice known femoral thrombosis cause cerebral embolism in a patient with a patent interventricular septum.

The arteries of the left side of the brain are the site of embolism more frequently than those of the right, and the left middle cerebral is the vessel most often affected. The point at which the embolus lodges depends upon its size. A large clot may be arrested in the internal carotid. A small one may pass to a cortical branch of one of the main arteries Following the lodgement of an embolus thrombosis usually occurs in the vessel and may spread distally, or less frequently proximally, into that in the area of brain deprived of its blood-supply (see p. 284). When the embolus is infected, meningitis or cerebral abscess may subsequently develop, or, when the infection is of low virulence, embolism may be followed by infective softening of the vessel wall and aneurysm formation. Such infective aneurysms may rupture into the subarachnoid space or into the brain (see p. 290).

Symptoms.

The onset of the symptoms of cerebral embolism is extremely sudden, the lodgement of the embolus occurring more rapidly than either cerebral haemorrhage or thrombosis. Loss of consciousness is not very common, but the patient is usually somewhat dazed. A convulsion may occur at the onset, and there is usually headache. The nature of the focal symptoms depends upon the vessel in which the embolus becomes impacted (see p. 284). After the onset of embolism there may be a gradual increase in the severity of the symptoms due to the development of oedema or to the extension of thrombosis proximally along the vessel. On the other hand, the symptoms may diminish in severity owing to the embolus becoming dislodged and passing to a more peripheral part of the vessel.

Diagnosis.

See diagnosis of Cerebral Haemorrhage, p. 303.

Prognosis.

Cerebral embolism as such is rarely fatal, unless the embolus lodges in the internal carotid. There is always, however, the risk that embolism of other organs may occur and the prognosis of the condition causing the embolism must be taken into consideration. As shock passes off and the oedema of the infarcted area of the brain diminishes, the extent and severity of the symptoms grow less, and the patient is finally left with such disabilities as result from destruction of the region of the brain supplied by the obstructed artery.

Treatment.

Treatment of the cerebral lesion is the same as that of cerebral thrombosis. The condition responsible for the embolism must also be dealt with appropriately.

Complete rest for several weeks is essential in order to diminish the risk of further emboli occurring. If embolism occurs in a patient receiving quinidine for auricular fibrillation, this drug must at once be suspended.

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8. HYPERTENSIVE ENCEPHALOPATHY

Definition: An acute and transitory disturbance of cerebral functions which occurs in association with high blood-pressure, in acute and chronic glomerulo-nephritis, malignant hypertension and eclampsia. The cardinal symptoms are convulsions and focal disturbances, such as amaurosis, aphasia, and hemiplegia.

Synonym: Acute uraemia.

Aetiology and Pathology.

The term hypertensive encephalopathy was first used by Oppenheimer and Fishberg (1928) to describe a form of cerebral disturbance occurring in disorders which differ in their pathology but possess a common tendency to cause arterial hypertension. The occurrence of such cerebral episodes in acute and chronic glomerulo-nephritis and in eclampsia at first suggested that they were the outcome of impaired renal function and that they were therefore considered uraemic in nature. This view has been discarded because not only are symptoms of this kind usually absent when renal function is

grossly impaired as a result of surgical lesions but they may be conspicuous in hypertensive states in which renal function, as judged by the blood chemistry, is normal. The constant presence of arterial hypertension, however, and especially the fact that the onset of the encephalopathy is not uncommonly preceded by a rapid rise in the blood pressure suggests that the disturbance of function is closely related to the hypertension. The view that it is the result of constriction of the cerebral arterioles or capillaries is plausible but at present unproved. It is perhaps supported by the observation of those who claim to have observed a concurrent spasm of the retinal arteries. Pathological observations have not yet solved the problem, for no constant pathological difference has been observed between the brains of patients dying of hypertensive encephalopathy and those of patients dying of the same causal condition without the cerebral disturbance. The commonest finding is oedema of the brain, but this is not always present and since oedema of the brain when due to other causes, such as intracranial tumour, does not necessarily lead to symptoms like those of hypertensive encephalopathy it seems likely that it is itself a by-product of the pathological process and not the cause of the symptoms. Lead encephalopathy in general resembles hypertensive encephalopathy and may be associated with hypertension, and there is experimental evidence that lead produces vasoconstriction by acting directly upon the smooth muscles of the vessels.

The age incidence of hypertensive encephalopathy is that of the causal disorders. Acute glomerulo-nephritis is commonest in childhood, adolescence, and early adult life; chronic glomerulo-nephritis in the second and third decade; eclampsia during the early part of the child-bearing period; and malignant hypertension in the thirties and forties, though it may occur in childhood or late middle age.

Symptoms.

The onset of symptoms is usually sub-acute, the patient complaining of headaches of increasing severity, which are often associated with vomiting of a cerebral type. Epileptiform convulsions are common and may be followed either by mental confusion or coma. Impairment of vision, or even complete blindness, may occur. This is cerebral in origin, for there too may be normal and during recovery of vision one homonymous pair of visual half-fields may recover before the other. Other focal cerebral disturbances include aphasia and hemiparesis.

Arterial hypertension is present in every case, but the blood-pressure may be not greatly raised in acute nephritis and eclampsia. A rise in an already high blood pressure frequently heralds the

encephalopathy. The retinae may be normal or there may be bilateral papilloedema with or without the exudative changes of hypertensive retinopathy, depending upon the causal condition. Evans (1933) draws attention to the occurrence of puffiness of the face, the onset and disappearance of which often coincides with the onset and cessation of the encephalopathic symptoms Cervical rigidity, tachycardia, and fever sometimes occur. Both renal function and the composition of the urine may be normal except when the encephalopathy complicates acute or chronic renal damage The pressure of the cerebro-spinal fluid is often increased, but may be normal, *and its composition is normal.*

Diagnosis.

Hypertensive encephalopathy must be distinguished from uraemia, cerebral vascular lesions such as haemorrhage and thrombosis, and intracranial tumour In uraemia convulsive phenomena consist usually of myoclonic twitches rather than of epileptiform attacks and amaurosis is rare Cerebral vascular lesions do not produce such a diffuse picture of cerebral disturbance and are never as transient as the symptoms of encephalopathy The diagnosis from intracranial tumour may be very difficult in the presence of papilloedema and a raised pressure of cerebro-spinal fluid, since cerebral tumour may occur in a patient who also has hypertension. In doubtful cases ventriculography should be carried out. The examination of the urine and blood-pressure will enable convulsions due to encephalopathy complicating acute nephritis in childhood to be distinguished from epilepsy, and in doubtful cases examination of the cerebro-spinal fluid will exclude meningitis.

Prognosis.

Alarming though the symptoms are, the outlook in hypertensive encephalopathy is on the whole good as to recovery from the cerebral disturbance, though the ultimate outlook depends upon the underlying cause. Most patients recover from encephalopathy complicating acute nephritis and from eclampsia. Even in malignant hypertension the patient may recover from the encephalopathy. Severe and frequent convulsions are a bad sign. Recovery from the *amaurosis, aphasia, and other focal symptoms is usually complete* in a few days.

Treatment.

Venesection should be carried out at once, 400–600 c c of blood being withdrawn according to the age of the patient. Lumbar puncture should also be performed *and repeated if necessary.*

Morphia should be given, and if the convulsions prove intractable barbiturates also, preferably by the rectum. In severe cases the rectal administration of hypertonic magnesium sulphate solution (6–8 oz. of a 25 per cent. solution) may be tried. The treatment appropriate to the causal condition will also be required.

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9. THE CEREBRAL VENOUS CIRCULATION

THE VENOUS SINUSES

The intracranial venous sinuses are spaces lying between layers of the dura mater and are lined with endothelium. They receive blood from the veins of the brain and directly or indirectly drain into the internal jugular vein. They communicate with the meningeal veins and by emissary veins with the veins of the scalp.

The following sinuses are unpaired:

The Superior Longitudinal Sinus.

The superior longitudinal sinus begins anteriorly at the crista galli, where it communicates through the foramen caecum with the nasal veins, and passes upwards, backwards, and finally downwards at the convex upper margin of the falx. It ends at the level of the internal occipital protuberance by turning, usually to the right, into the right lateral sinus. Occasionally it turns into the left lateral sinus. It possesses a terminal dilatation—the torcular Herophili—from which a communicating channel passes to the junction of the straight sinus and the left lateral sinus. The superior longitudinal sinus receives the superior group of superficial cerebral veins and thus drains the upper part of the cerebral hemispheres.

The Inferior Longitudinal Sinus.

The inferior longitudinal sinus lies in the free lower border of the falx for its posterior two-thirds and terminates posteriorly by joining the great vein of Galen to form the *straight sinus*, which passes between layers of the dura along the line of junction of the falx with the tentorium. Posteriorly it turns to the left at the level of the internal occipital protuberance to become the left lateral sinus.

The following sinuses are paired:

The Lateral Sinuses.

The lateral sinuses arise posteriorly, the right from the superior longitudinal sinus, the left from the straight sinus, and pass laterally and forwards in the attached border of the tentorium, lying in a groove in the occipital bone. Each then turns downwards on the inner surface of the mastoid process and leaves the skull by the jugular foramen, to enter the internal jugular vein.

The Cavernous Sinuses.

The cavernous sinuses lie one on either side of the body of the sphenoid. They begin anteriorly at the inner end of the sphenoidal fissure, where they receive the ophthalmic veins, and terminate posteriorly at the apex of the petrous portion of the temporal bone by dividing into the superior and inferior petrosal sinuses. In the lateral wall of the cavernous sinus lie the internal carotid artery with its sympathetic plexus, the third and fourth nerves, the first and second divisions of the fifth nerve, and the sixth nerve.

The Superior Petrosal Sinuses.

The superior petrosal sinuses run backwards and laterally along the attached edge of the tentorium, to end in the lateral sinuses.

The Inferior Petrosal Sinuses.

The inferior petrosal sinuses run backwards, outwards, and downwards in the posterior fossa, to join the internal jugular veins by passing through the jugular foramina.

The Cerebral Veins.

The venous sinuses receive as tributaries the cerebral veins. The superficial cerebral veins are divided into two groups—the superior, which run upwards to the superior longitudinal sinus and drain the upper halves of the hemispheres, and the inferior, which drain the lower halves of the hemispheres and run downwards to join the venous sinuses of the base. The most important of the deep cerebral veins is the great vein of Galen, which drains the choroid plexuses of the third and lateral ventricles and the basal ganglia, and terminates by joining the inferior longitudinal sinus to form the straight sinus.

The Diploic Veins.

The venous channels in the bones of the skull, the diploic veins, drain either into the venous sinuses or into the superficial veins of the scalp.

(References, see p. 322.)

10. THROMBOSIS OF THE INTRACRANIAL VENOUS SINUSES

Aetiology.

Thrombosis of the intracranial venous sinuses is usually the result of the extension of infection to the sinuses from neighbouring structures or of direct injury. Rarely it occurs in the absence of any evident local cause in conditions of marasmus or cachexia. These two varieties of sinus thrombosis are rather unsatisfactorily distinguished as secondary' and 'primary' respectively.

Primary' sinus thrombosis is rare and is most frequently seen at the extremes of life, especially during the first year. It occurs in wasted, debilitated infants and later in life in individuals suffering from severe anaemia, exhausting infections such as enteric, or emaciating diseases such as carcinoma and phthisis. The principal predisposing factors of 'primary' sinus thrombosis appear to be anaemia, increased coagulability of the blood, slowing of the blood-stream as a result of a low blood-pressure, and dehydration. It may form part of the picture of thrombo-phlebitis migrans.

'Secondary' sinus thrombosis may be the result of direct injury of a sinus through fracture of the skull or surgical operation in its vicinity, or puncture of the superior longitudinal sinus in infancy for therapeutic purposes. Infection may spread to the sinuses from an area of osteitis of one of the cranial bones. The lateral sinus may thus become infected from mastoiditis or through the jugular vein from the throat. Infection may spread from the lateral to the superior longitudinal sinus. The latter and the cavernous sinus may be directly infected from frontal sinusitis or from infection of the other nasal air sinuses. Owing to the comparatively free communication between the intracranial venous sinuses and the superficial veins of the face and scalp, cutaneous infections, such as boils, carbuncles, and erysipelas, in these regions, may cause intracranial sinus thrombosis. The cavernous sinus is especially liable to become infected as a result of pyogenic infections in the neighbourhood of the upper lip. The source of infection may be remote from the head, e.g. puerperal. Though sinus thrombosis may be the only manifestation of infection, it may be associated with extradural or subdural abscess, intracerebral abscess, or localized or diffuse leptomeningitis.

Pathology.

The affected sinus contains a reddish clot, which tends in time to become paler and adherent to the sinus wall. In sinus thrombophlebitis due to pyogenic organisms the clot may become purulent. It may extend into tributary veins or into other sinuses. The internal

jugular vein is frequently involved by extension from the lateral sinus. The area of brain drained by the affected sinus exhibits congestive oedema and in some cases softening, and the development of some degree of collateral venous circulation causes congestion of neighbouring veins. Obstruction of a large sinus, such as the superior longitudinal, may so impede the absorption of cerebro spinal fluid that hydrocephalus results. Extension of infection from the sinus may cause localized or diffuse leptomeningitis or intracerebral abscess, while the liberation of organisms or of fragments of infected clot into the general circulation may lead to pyaemia and pyaemic abscesses, especially in the lungs.

Symptoms.

The symptoms in intracranial venous sinus thrombosis consist of (1) symptoms of the predisposing condition; (2) symptoms of obstruction to the venous drainage of tissues adjacent to the sinus; (3) in the case of infective thrombophlebitis, symptoms of extension of the infection to neighbouring structures and of its dissemination in the blood-stream; and (4) radiographic investigation is sometimes helpful.

(1) Conditions predisposing to intracranial sinus thrombosis have already been mentioned in the section dealing with aetiology.

(2) The symptoms due to *obstructed venous drainage* differ according to the sinus affected.

Thrombosis of the Cavernous Sinus. Pain is severe and is located in the eye and forehead on the affected side and is usually associated with hyperalgesia over the cutaneous distribution of the ophthalmic division of the trigeminal nerve There is conspicuous oedema of the eyelids, the cornea, and the root of the nose, associated with exophthalmos due to congestion of the orbital veins. Papilloedema is sometimes present, in which case vision is markedly reduced and may be lost, but in other cases the optic disk is normal and vision is little impaired. Since the third, fourth, and sixth cranial nerves lie in the lateral wall of the sinus, ocular palsies are usually present and there may be complete internal and external ophthalmoplegia. Cavernous sinus thrombosis is usually unilateral at the outset, but thrombo-phlebitis readily extends through the circular sinus to the cavernous sinus of the opposite side, the signs then becoming bilateral.

Thrombosis of the Superior Longitudinal Sinus. Thrombosis of the superior longitudinal sinus usually occurs in infancy and leads to a considerable rise of intracranial pressure. The earliest symptoms consist of headache, vomiting, delirium, and in some cases head retraction and convulsions. There is marked congestion of the veins

of the scalp and sometimes also of the nasal veins, and in infants the fontanelle is tense. Papilloedema is sometimes present and squint may occur. Since the superior longitudinal sinus receives the superior cortical veins which drain the upper half of the hemispheres, and since the lower limbs are represented in the areas of the pre-central gyrus nearest the vertex, thrombosis of this sinus may cause symptoms of bilateral pyramidal lesions, which are most marked in, and may be confined to, the lower limbs. Focal symptoms may be unilateral, e.g Jacksonian epilepsy and hemiplegia, or even absent. The symptoms may be mainly or exclusively those of hydrocephalus, as in so-called " otitic hydrocephalus " (see p. 211).

Thrombosis of the Lateral Sinus. Thrombosis of the lateral sinus is almost always the result of an extension of infection from the mastoid. The patient complains of headache and of pain in the ear, which tends to be intensified by moving the head. Vomiting may occur. Venous congestion may be observed in the neighbourhood of the mastoid process and extension of the phlebitis to the jugular vein causes tenderness in the neck. The vein is sometimes, though only exceptionally, palpable as a tender cord. Papilloedema is sometimes present, but is usually slight and may be confined to the eye of the affected side. Delirium may occur, but focal cerebral symptoms are usually inconspicuous, though slight signs of a pyramidal lesion are not uncommon, especially facial weakness and an extensor plantar response on the opposite side. Slight aphasia may be present when the left lateral sinus is affected.

The cerebro-spinal fluid is usually under increased pressure, but may be otherwise normal. In thrombosis of the superior longitudinal sinus, however, it is not uncommon to find red blood-cells in considerable numbers, with a corresponding rise in the protein content, and even a xanthochromic fluid. The presence of a slight excess of leucocytes, usually both polymorphonuclear and mono-nuclear, is not uncommon and indicates a localized extension of the infection to the neighbouring leptomeninges. When one lateral sinus is filled with clot the pressure of the cerebro-spinal fluid may fail to show the normal rise when the jugular vein on the affected side is compressed alone in Queckenstedt's test, but the sinus may be infected without being obstructed.

(3) Intracranial sinus thrombosis of infective origin usually leads to *general symptoms* resulting from the passage of organisms into the blood-stream. The patient is extremely ill, with a swinging temperature and rapid pulse, and rigors are common. Detachment of fragments of clot with resulting pulmonary embolism is most likely to occur in the case of lateral sinus thrombosis with extension to the jugular vein. This event is indicated by a sudden pain in the chest,

associated with dyspnoea and sometimes with haemoptysis, followed by the development of signs of pulmonary consolidation and frequently a pleural rub. Pulmonary abscess may follow. The commonest intracranial extension of the infection is to the leptomeninges, resulting in many cases in a diffuse leptomeningitis. This event is characterized by an increase in the severity of the headache, the development of cervical rigidity, the presence of Kernig's sign and other symptoms of meningitis, together with a marked polymorphonuclear pleocytosis with or without organisms in the cerebro-spinal fluid.

(4) Radiography of the sinuses after the injection of an opaque substance, perabrodil, may yield evidence of obstruction (Frenckner, 1936).

Diagnosis.

Cavernous sinus thrombosis may occasionally be confused with other lesions in the neighbourhood of the sphenoidal fissure. Similar local symptoms may be produced by aneurysm of the cavernous sinus following rupture into it of the internal carotid artery This, however, as a rule follows trauma, of which a history is obtainable. Pulsation is present in the eye and a bruit is audible to the patient and often to the observer. Symptoms of infection are absent. Compression of the cavernous sinus by intracranial tumour is of gradual onset and is unassociated with symptoms of infection.

Thrombosis of the superior longitudinal sinus, when it occurs in infancy, may be difficult to distinguish from hydrocephalus, to which it often gives rise The selective paralysis of the lower limbs, when this is present, is the most useful distinctive feature. Examination of the cerebro-spinal fluid will enable sinus thrombosis to be distinguished from meningitis.

Lateral sinus thrombosis may be difficult to distinguish from other intracranial complications of mastoiditis, especially extradural, subdural, and intracerebral abscess, with any of which it may coexist. When any of these conditions is suspected, however, the region of the lateral sinus should be explored and the dura and the sinus itself inspected.

Prognosis.

The prognosis of intracranial venous sinus thrombosis is always grave and the mortality is high. The outlook is best in the case of lateral sinus thrombosis secondary to mastoiditis, since this is amenable to surgical treatment. Recovery from thrombosis of the cavernous sinus is rare. After thrombosis of the superior longitudinal sinus the patient may be left with hydrocephalus.

Treatment.

When sinus thrombosis is infective in origin the source of infection must receive appropriate treatment. In the case of lateral sinus thrombosis the jugular vein should be ligatured as a safeguard against pyaemia. Sulphanilamide or allied drugs should be given as for meningitis. Otherwise treatment is symptomatic.

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INJURIES OF THE BRAIN

I. THE IMMEDIATE EFFECTS OF HEAD INJURY

Aetiology and Pathology.

DURING recent years head injuries have occurred with increasing frequency, owing to the high speed of modern life. In civil life most head injuries are due to direct violence resulting from motor and industrial accidents. Less frequently they are produced by indirect violence after falls on the feet or buttocks. Penetrating wounds of the brain are comparatively rare. There is no direct parallelism between the severity of an injury to the skull and the extent to which the brain is damaged. Though, naturally, severe fractures of the skull are associated with severe cerebral injury, the brain may be extensively damaged without the skull being fractured and, on the other hand, fracture of the skull may occur without severe damage to the brain. Compound fractures of the skull, especially fractures involving the base and extending into the nasopharynx, nasal air sinuses, middle ear, and mastoid, assume additional importance as liable to lead to infection of the intracranial contents and thus to cause meningitis or intracranial abscess. Apart from this risk, however, the crucial question after a head injury is the state of the brain rather than the state of the skull, and this alone will be considered here. For the characteristics of fractures of the skull and the details of their surgical treatment the reader is referred to text-books of surgery.

Following an injury to the head the patient may suffer from (1) concussion, (2) cerebral contusion, (3) cerebral laceration, (4) cerebral compression.

Concussion.

Concussion has been defined by Trotter as 'a condition of wide-spread paralysis of the functions of the brain which comes on as an immediate consequence of a blow on the head, has a strong tendency to spontaneous recovery, and is not necessarily associated with any gross organic change in the brain substance'. Concussion is thus essentially a disturbance of function and has received various explanations. It has been ascribed to an acute cerebral anaemia, but Miller has shown that the physiological response to concussion differs from that which follows acute cerebral anaemia. Mott ascribed concussion to the effects of a sudden massive displacement of the cerebro-spinal fluid into the cerebral perivascular spaces, Greenfield

(1938–9) to stretching or deformation of nerve-tracts especially those passing to the thalamus, and other hypotheses have been proposed Whatever the precise explanation, it is clear that, directly or indirectly, a blow on the head of sufficient severity produces an immediate depression of cerebral function, which is to some extent proportionate to the violence of the blow.

Cerebral Contusion.

Cerebral contusion is a more or less diffuse disturbance of the brain following head injury and characterized by oedema and capillary haemorrhages. A number of recent workers have shown that in fatal cases of head injury multiple intracerebral haemorrhages are usually found These are most frequently present at the poles of the hemispheres (Jefferson). Microscopical examination shows more widely scattered punctate haemorrhages and widespread cerebral oedema leading to distension of the perivascular sheaths and of the pericellular spaces. Disturbances in the circulation of the cerebro-spinal fluid play an important part in the production of symptoms. The pressure of the fluid is usually raised but may be subnormal. In the former case there may be increased formation of fluid, and there is possibly diminished absorption owing to blockage of the arachnoid villi by haemorrhage. Rand has shown that in severe cases of head injury changes which include oedema and increased vacuolation are present in the choroid plexuses and ependymal cells. In addition, the circulation of the fluid may be impeded by meningeal adhesions, and rupture of the arachnoid may lead to the formation of encysted subdural collections of fluid. Greenfield (1938–9) has drawn attention to the occurrence of localized severe demyelination which he considers a late result of oedema.

Cerebral Laceration.

'Cerebral laceration' is the term used when a cerebral contusion is sufficiently severe to cause a visible breach in the continuity of the brain substance. This may occur either immediately beneath the site of the blow or by *contre-coup* on the opposite side of the brain.

Cerebral Compression.

Cerebral compression occurs when the injury is followed by intracranial haemorrhage, which may be either subdural or extradural, the former, according to Vance, being more than twice as common as the latter. Acute subdural haemorrhage is usually the result of a severe laceration, which may either involve the surface of the hemisphere or cause a large cavity filled with blood within its substance. Less often acute subdural haemorrhage is due to rupture of

venous tributaries of the superior longitudinal sinus or to laceration of one of the venous sinuses. Extradural haemorrhage is usually due to laceration of the middle meningeal artery by fractured bone, the posterior branches being involved more often than the anterior.

Symptoms.

Concussion

Following a slight injury the patient may be merely dazed or unconscious for a few seconds only, but his higher mental functions may subsequently be impaired for a period lasting up to several hours, during which he may carry out complicated activities in an automatic fashion, afterwards remembering nothing of these events This loss of memory may also extend to incidents which occurred before the accident, and is then known as *retrograde amnesia.* For example, a patient who sustains a head injury as a result of an aeroplane crash may remember nothing that happened after he left the ground; or one who has been injured in a motor accident may forget the incidents of a long drive.

In cases of more severe injury unconsciousness is more prolonged, and in addition the patient exhibits impairment of the functions of the brain-stem, especially of the medulla. The pupils may be dilated and may fail to react to light, and the cutaneous and tendon reflexes may be lost, the musculature being flaccid. The skin is pale and bleeds little when injured. The blood-pressure is low and the pulse is slow, or, in some cases, rapid and feeble or imperceptible. Respiration may stop or may be shallow and sighing. Though death may occur in severe cases from medullary paralysis, it is probable that in most fatal cases cerebral contusion is present as well as concussion.

Recovery from concussion is manifested first in an improvement of visceral function, the volume of the pulse increases, respiration becomes deeper, and the pupils again react to light. Vomiting is common at this stage. On recovering consciousness the patient may be delirious, restless, and irritable, and almost always complains of headache. In cases of uncomplicated concussion, however, these symptoms, with the exception possibly of headache, disappear within forty-eight hours after the injury.

Cerebral Contusion.

Slight cerebral contusion may occur in the absence of concussion. In most cases, however, the patient is rendered unconscious by the injury. In the most severe cases the depth of coma steadily increases and the patient dies from medullary paralysis within a few hours of the receipt of the injury. In less severe cases the patient, after recovering from concussion, passes into a state of stupor or mental

confusion. He is usually drowsy and presents the picture long known as 'cerebral irritation', but better described as traumatic delirium (Symonds), lying in a flexed attitude, resenting interference, confused and disorientated when roused, and at times noisy and violent. This condition may last for days or even for weeks, and in favourable cases gradually passes away. Symptoms of a focal lesion of the brain are usually absent, but focal convulsions, hemiparesis, or aphasia may follow a contusion involving the cortex; injury to the midbrain may lead to ocular palsies, diplopia, and nystagmus; cranial nerve palsies may be present (see below); and diabetes insipidus is a rare complication.

Acute Traumatic Cerebral Compression.

Cerebral compression leads to progressively deepening unconsciousness, indicated by the failure of the patient to respond to stimuli which have previously been capable of rousing him, and by loss of corneal reflexes. Deepening coma is of special importance when it follows a lucid interval after concussion. Ocular symptoms are important, the pupil on the side of the haemorrhage being first contracted and later dilated and failing to react to light, the same sequence of events subsequently occurring on the opposite side (Hutchinson). Papilloedema is usually absent, though the optic disks and fundi may exhibit venous congestion. Symptoms of a progressive lesion of one cerebral hemisphere are frequently present. Focal convulsions indicate irritation of the motor cortex and may be produced either by a laceration or by compression following an extradural haemorrhage, especially from the anterior branches of the middle meningeal artery. Flaccid paralysis of one side of the body associated with a unilateral extensor plantar response indicates compression or destruction of the opposite hemisphere. Medullary symptoms are prominent, especially in the later stages of cerebral compression. The pulse at first is slow and full, later rapid, thready, and irregular. The blood-pressure may be subnormal or may exhibit a steady rise. The respirations are at first slow and deep, later irregular, e.g. of the Cheyne-Stokes type, and finally rapid and shallow. The temperature is often somewhat raised and may be unequal in the two axillae following a lesion of one hemisphere. Sugar may be present in the urine.

Cerebro-spinal Fluid.

Examination of the cerebro-spinal fluid may yield information of value, but lumbar puncture is not entirely free from risk after head injury. It should not be performed, therefore, until the patient has recovered from the immediate shock of the accident, and on the

first occasion only sufficient fluid for diagnostic purposes should be withdrawn. Blood is present in the fluid immediately after the accident in most cases of cerebral contusion and of more serious injury. The number of red cells present is not always proportionate to the severity of the injury, the protein content of the fluid is proportionate to the number of red cells. The supernatant fluid is xanthochromic. The red cells tend to disappear in four or five days, but the xanthochromia may remain for two or three weeks. The pressure of the fluid should always be determined by manometry, with the patient lying on his side and as far as possible relaxed. In most cases of severe head injury the pressure of the fluid is raised and may be as high as 200 to 300 mm. of fluid. Exceptionally, the pressure is normal or subnormal. In cases of suspected progressive cerebral compression a progressive rise in the pressure of the fluid at successive lumbar punctures affords confirmatory evidence, but the pressure of the fluid must always be considered in relation to clinical observations. In the late stages of cerebral contusion, that is weeks or months after the injury, the pressure is above 200 mm. of fluid in about 50 per cent of cases, but may be subnormal, a point of importance in determining the appropriate treatment.

Radiography.

Radiography during the acute stage may demonstrate an unsuspected fracture of the skull, which often proves of greater medicolegal than clinical importance. In the late stages of cerebral contusion, radiography after the introduction of air into the spinal subarachnoid space—encephalography (p. 240)—may throw light upon the causation of symptoms.

Variations from the normal encephalogram have been described in 80 per cent. of cases. The shape of the cerebral ventricles may be abnormal (Fig. 40), and there is often an abnormality in the distribution of the air over the cerebral cortex. Air may fail to reach certain areas owing to meningeal adhesions.

Other Investigations.

Inspection and palpation of the scalp and skull form part of the routine examination of cases of head injury, the presence of haematomas being noted and the bones carefully examined for depressed fracture. Bleeding from the nasopharynx and ears in the absence of external injury is an important symptom of fracture of the base of the skull, and inquiry should always be made as to the discharge of cerebro-spinal fluid, which may be recognized by its reduction of Fehling's solution. The urinary output should be measured from the beginning, lest traumatic diabetes insipidus should remain unnoticed.

Diagnosis.

Although in most cases the injury to the head is clearly the cause of the patient's symptoms, it is necessary to bear in mind the possibility that a pre-existing illness, especially a cerebral vascular lesion, may have led to an accident in which the head has been injured, in which case the symptoms may not be due to the injury. When this source of confusion has been eliminated it is necessary to decide the nature of the injury to the brain. If after a head injury the patient remains unconscious more than a few minutes, or if after recovery from the concussion he remains mentally confused or exhibits other symptoms of cerebral disturbance, the conclusion should be drawn that structural damage to the brain has occurred, and this may be confirmed by the presence of blood in the cerebro-spinal fluid. The symptoms which distinguish acute traumatic cerebral compression from cerebral contusion have already been described. The onset of meningitis is to be suspected when the patient develops marked cervical rigidity or Kernig's sign, and is confirmed by the presence of a marked polymorphonuclear leucocytosis, with or without pyogenic organisms, in the cerebro-spinal fluid.

When mental confusion and drowsiness increase in severity or persist for several weeks the possibility of subdural haematoma must be considered When this is present the symptoms tend to get worse with the passage of time, whereas in contusion the early symptoms tend to improve. Progressive symptoms in the later stages, therefore, whether general or focal, render exploration of the subdural space advisable.

After recovery from the acute symptoms it may be necessary to distinguish cerebral contusion from neurosis following the injury. This distinction is of considerable importance in the litigation which frequently follows head injury. Difficulty arises from the facts that focal signs are usually absent in cerebral contusion and that certain mental symptoms are common to both cerebral contusion and anxiety neurosis. In establishing the diagnosis of contusion stress must be laid upon the constancy of the clinical picture, especially in respect of the character of the headache, and the factors which precipitate it. It must be remembered, however, that when a patient is incapacitated for work by cerebral contusion, and especially when litigation is pending, anxiety neurosis is apt to complicate the condition.

Prognosis.

Concussion is rarely fatal and, when the patient survives the immediate effects of the injury, is followed by complete recovery within

a few days, provided it is not complicated by contusion or more serious injuries.

Contusion, when severe, may prove fatal, usually within a few hours, from medullary paralysis. Less often the patient lingers in a semiconscious condition for several days, and death then occurs from exhaustion or pneumonia. Death from cerebral contusion, *however, is exceptional. In those who recover from the immediate effects of the injury* contusion often causes symptoms, the persistence and disabling character of which appear to be disproportionate to the severity of the injury. Symonds has investigated the outcome in a group of patients suffering from cerebral contusion, excluding mild and quickly recovering cases. Ten per cent. were totally incapacitated, 43·5 per cent. were able to return to light work, and 46·5 per cent. were able to return to full work. When the patients were divided into two groups according to whether or not the injury had been followed by a stage of mental confusion, it was found that the prognosis with regard to working capacity was considerably worse in those who had exhibited such mental confusion than in those who had made a rapid recovery from the immediate effects of the injury.

Acute traumatic cerebral compression is fatal in the majority of cases, the outlook being worse when the haemorrhage is subdural than when it is extradural. In most of Vance's cases death occurred within twenty-four hours. In a few the patient lived for from one to two weeks.

Meningitis following head injury is almost invariably fatal, though the patient may live for days or even for weeks. Late results of head injuries, which include persisting symptoms of injuries to the hypothalamus and midbrain (such as diplopia, Parkinsonism, and diabetes insipidus), cranial nerve palsies, intracranial aerocele, cerebro-spinal rhinorrhoea, subdural haematoma, and traumatic epilepsy, are described elsewhere.

Treatment.

Concussion.

If breathing stops, artificial respiration must be carried out until medullary paralysis passes off. The patient should be kept in bed in a darkened room and should be given sedatives, and, if the headache is severe, analgesics, together with a saline purge. Concussion in itself does not necessitate the patient remaining in bed more than three or four days, but since it is impossible in many cases to be sure that a mild cerebral contusion has not occurred, the patient should, if possible, be kept in bed at least a week, and if headache is still present or develops on getting up, the treatment of contusion should be instituted,

Contusion

If there is any reason to suspect that the brain has been bruised the patient should be kept in bed for at least three weeks, even in the mildest cases. In the early stages sedatives will be required, especially at night Paraldehyde, medinal, or luminal may be used. Severe restlessness should be treated by morphine or subcutaneous injection of 2 grains of luminal sodium, or 3 or 4 drachms of paraldehyde in 2 oz. of olive oil per rectum. The pressure of the cerebro-spinal fluid should be ascertained by lumbar puncture manometry. When the pressure is raised sufficient fluid should be withdrawn to reduce it to normal, and lumbar puncture may be repeated for this purpose as necessary. Dehydration has proved of less value in the treatment of cerebral contusion than in the reduction of increased intracranial pressure due to a cerebral tumour. This is probably because in contusion the paths by which fluid is absorbed from the nervous system are themselves damaged. Dehydration is not without risk in the acute stage of head injury, and one fatality has been reported following its use. It should not be employed when the patient is profoundly shocked. The rectal administration of 8 oz. of 25 per cent. magnesium sulphate solution is probably free from risk. . For intravenous injection 100 c.c of 50 per cent. sucrose solution should be used, the rate of injection not exceeding 3 c.c. a minute. In the later stages, hypertensive headache may be relieved by encouraging the patient to sleep in a sitting position, propped up with pillows, while the headache associated with a subnormal pressure of cerebro-spinal fluid may be ameliorated by keeping the patient recumbent and elevating the foot of the bed on blocks. When the stage of mental confusion is passed the patient should still be kept very quiet. At this stage a mixture containing potassium bromide with 30 or 40 grains of magnesium sulphate thrice daily will act as a sedative and at the same time lower the intracranial pressure. When headache and other symptoms persist in spite of medical treatment they are sometimes relieved by the injection of air in amounts up to 100 c.c. into the spinal subarachnoid space after lumbar puncture. The method is the same as in encephalography (see p. 240). This is a somewhat painful procedure and is by no means always effective.

In all cases of cerebral contusion convalescence should be prolonged and return to work gradual.

Acute Traumatic Cerebral Compression.

Surgical interference during the acute stage of head injury, apart from that necessitated in the treatment of compound fracture of the skull, should be confined to cases in which symptoms of progressive

cerebral compression are present, the brain being explored in the region indicated by the nature of the symptoms. Even in such cases operation should not be carried out during the stage of shock, since if the patient does not rally from the immediate effects of the injury it is unlikely that surgical interference will be effective.

2. LATE EFFECTS OF HEAD INJURY

GENERAL AND MENTAL SYMPTOMS

Though a patient may recover rapidly and completely from a cerebral contusion persistent disabling symptoms are extremely common. The three cardinal late symptoms are headache, giddiness, and mental disturbances, and they usually develop out of the symptoms of the acute stage. Headache tends to be severe and to occur in paroxysms which may last several hours, often against a background of continuous pain. It is brought on or exacerbated by activities such as stooping, sneezing, physical exertion, and excitement. When the headache is associated with a raised pressure of the cerebro-spinal fluid it tends to be increased by lying and relieved by sitting. When the pressure of the fluid is low the reverse is the case. The giddiness is not usually a sense of rotation, but a feeling of instability.

The commonest mental symptoms are inability to concentrate, fatiguability, impairment of memory, together with nervousness and anxiety. These are in fact symptoms of mild dementia of traumatic origin and all grades are encountered between the common milder cases and the less frequent more severe examples.

In the latter the patient passes from the initial stupor into a stage of profound disorientation and confusion with defects of perception and disorganization of speech, and then into a stage resembling Korsakow's psychosis with gross defects of memory for recent events and sometimes confabulation. The final picture depends on many factors especially the psychological constitution of the patient. Residual mental inefficiency is not uncommon; severe dementia very rare. Moods of excitement or depression are not infrequent in cyclothymic individuals.

Traumatic organic mental abnormalities need to be distinguished from traumatic neurasthenia. In the former the impaired mental capacity especially the response to specific tests, and the constancy of the cranial symptoms, headaches, &c., are distinguishing features.

CRANIAL NERVE PALSIES

Cranial nerve palsies are not strictly late effects of head injury, since they are produced at the time of the accident, but since they

frequently persist after the acute stage they are conveniently considered in this section. Cranial nerve palsies may be due to injury of the brain-stem or of the nerves, either in their intracranial or in their extracranial course. Contusion of the midbrain may leave permanent paresis of ocular movement, usually in the vertical plane, either unilaterally or bilaterally, resulting in diplopia and often associated with nystagmus. Intracranial injuries of the nerves are usually the result of fracture of the base of the skull. The seventh is the nerve most frequently affected and after that the eighth, sixth, second, third, and fourth in this order (Sherren). The olfactory nerves may be involved with or without fracture passing through the anterior fossa. The effects of injuries of these nerves are described in the sections dealing with the cranial nerves. The facial nerve, or its branches, and branches of the trigeminal may be divided or contused as a result of wounds and blows upon the face. Traumatic cranial nerve palsies are usually permanent, the only exception being those which are due to contusion of extracranial branches.

TRAUMATIC PNEUMOCEPHALUS

Definition: The pathological presence of air within the skull as a result of head injury.

Synonym: Intracranial acrocele.

Aetiology and Pathology.

The presence of air or gas within the cranial cavity is occasionally the result of infection with gas-forming organisms. Thus a bubble of gas may exceptionally be found within the cavity of an intracranial abscess. Ventriculography and encephalography utilize for purposes of diagnosis air which has been intentionally introduced into the cranial cavity by the operator. Occasionally air enters the skull as a result of erosion of bone from within, for example, by intracranial tumour (Fig. 27), abscess, or hydrocephalus. Trauma, however, is by far the commonest cause of the pathological presence of air within the skull. This is usually due to a fracture of the skull affording communication between an air-containing cranial cavity and the interior of the skull. This may occur as the result of a fracture which involves the frontal, ethmoidal, or sphenoidal sinuses or the mastoid air cells or, occasionally, after operation on a nasal sinus. It is rare for a fracture of the cranial vault to be followed by the entry of air within the skull.

The factors which influence the passage of air into the skull have been much discussed. The most important is probably the circumstance that in a normal individual in an upright posture the pressure of cerebro-spinal fluid within the skull is less than the atmospheric

pressure. If, therefore, there is a free communication through the bone and the dura, air will tend to be aspirated in these circumstances into the skull until the intracranial pressure equals the atmospheric pressure. This process may be facilitated by actions such as sneezing, swallowing, and blowing the nose, which raise the pressure within the nasal air sinuses. The opening in the dura may operate as a valve which permits the entry of air but prevents its exit. Within the cranial cavity the collection of air may be external to the brain Both subdural and subarachnoid collections have been described, but as the arachnoid is often torn, it is difficult to discriminate these The air sometimes penetrates one cerebral hemisphere, in which it becomes encysted Occasionally it is even found within the ventricles, which it probably reaches as a result of a tear in the floor of the third ventricle, though it is possible that, as in encephalography, it enters the ventricles through the foramina of Luschka.

Symptoms.

Cerebro-spinal rhinorrhoea, a discharge of cerebro-spinal fluid from the nose, is usually an accompaniment of traumatic pneumocephalus It may, however, occur when the base of the skull is eroded from within by intracranial tumour, abscess, or internal hydrocephalus. The volume of the discharge is variable: it may be small or there may be enough to necessitate the use of a number of handkerchiefs The discharge is usually influenced by change of posture and may occur, for example, only when the patient sits up. It often affords relief from headache and other symptoms. The presence of sugar in the fluid can be demonstrated by Benedict's test and is a useful diagnostic point. In some cases of traumatic pneumocephalus an albuminous fluid has been discharged from the nose This is derived from an *intracranial air cyst.* The presence of air *within the skull* may occasionally be demonstrated by means of a tympanitic note on percussion, more frequently by succussion splash audible to the patient and to the observer on shaking the patient's head This last symptom implies the presence of both air and fluid within the intracranial cavity.

The presence of air within the skull may lead to focal symptoms, especially when it has invaded one cerebral hemisphere. The nature of these symptoms depends upon the situation of the air. They may include mental confusion, convulsions, aphasia, hemiparesis, and a grasp reflex. They tend to fluctuate in severity and may be relieved by an attack of *cerebro-spinal rhinorrhoea* Symptoms of increased intracranial pressure, for example headache and papilloedema, may also be present. In severe cases coma may develop.

X-ray examination of the skull is the most valuable single method of diagnosis, the situation of the air being exactly demonstrated. When fluid is also present within the cavity it may be demarcated from the air by a horizontal line which varies in position in relation to gravity.

Diagnosis.

Diagnosis offers little difficulty. All cases of serious head injury should be X-rayed and the presence of air is demonstrated by the radiograms.

Prognosis.

Two factors influence the prognosis in traumatic pneumocephalus, the risks of a focal lesion of the brain associated with increased intra-cranial pressure and the risks of meningitis due to infection entering the skull through the opening in the bone.

Air in the ventricles and in the subarachnoid space is absorbed in from ten days to a fortnight. It is doubtful, however, whether absorption occurs when the air is encysted by brain tissue. The risk of infection is high and in the large majority of cases of head injury with cerebro-spinal rhinorrhoea meningitis supervenes in the absence of operative interference.

Treatment.

In order to diminish the risks both of further entry of air within the skull and of meningeal infection, the patient should be kept flat and should be told to avoid forcibly blowing his nose. Saline purges are contra-indicated owing to the risks attendant upon lowering the intracranial pressure. Sulphanilamide should be given prophylacti-cally in doses of $\frac{1}{2}$ to 1 gramme thrice daily.

Operation must always be considered and will become necessary when serious symptoms are caused by the collection of air or by increased intracranial pressure and when cerebro-spinal rhinorrhoea continues.

If focal symptoms are diminishing and there is reason to believe that the fistula has closed, a waiting policy may be adopted.

The objects of operation are to evacuate the air and to close the opening in the dura.

Chronic Subdural Haematoma

Definition: An encysted collection of blood between the dura mater and the arachnoid, sometimes traumatic, but also occurring in the absence of recognized injury.

Synonym: Pachymeningitis interna haemorrhagica.

Pathology.

In chronic subdural haematoma blood slowly accumulates in the subdural space. Its origin is uncertain, but it has been suggested that it is derived from rupture of a vein running from the cerebral cortex to a dural venous sinus. It is possible that the bleeding is maintained by the fact that the blood compresses the veins or venous sinuses, thus causing venous congestion, and by a vicious circle further haemorrhage. Russell and Cairns (1935) in four cases of metastatic carcinoma of the dura complicated by subdural haematoma attributed the bleeding to engorgement and rupture of the capillaries of the areolar layer. In most cases the collection of blood, which may attain a large size, lies over the frontal and parietal lobes, and in nearly half of all cases the haematoma is bilateral. The blood is encysted between an outer wall consisting of a layer of highly vascularized granulation tissue slightly adherent to the dura, and a thinner, inner wall of fibrous tissue with a single layer of mesothelium on the side next to the arachnoid. It is mostly fluid, though a coagulum may be present.

Aetiology.

Males are affected more often than females in the ratio of five to one. Subdural haematoma may occur at any age. It is sometimes seen in infancy when it has been attributed to birth injury, but is most common in the elderly. Trauma is the commonest cause. Other causes include chronic alcoholism, neurosyphilis, streptococcal infections, blood diseases such as scurvy and thrombocytopenic purpura, and carcinoma of the dura. Whatever the cause the pathological condition of the dura appears to be the same (Russell and Cairns).

Symptoms.

The symptoms of subdural haematoma may follow an injury immediately. More frequently, however, there is a latent interval lasting weeks or months, less often more than a year, rarely of many years. During the latent interval the patient may be free from symptoms or may complain of symptoms suggestive of cerebral contusion. After the latent interval there is a gradual onset of headache, drowsiness, and, often, mental confusion. These symptoms often fluctuate greatly in severity. As is usually the case when the brain is compressed from without, focal cerebral symptoms may be lacking or slight, considering the size of the haematoma. When present they are likely to consist of hemiparesis, with motor aphasia when the lesion is left-sided. The grasp reflex may be present. Papilloedema is often absent. Transient ocular paralysis may occur. The cerebro-spinal fluid is usually normal, but the protein may be increased,

and the fluid may be xanthochromic. Ventriculography may be of value in a doubtful case by demonstrating displacement of the ventricular system to the opposite side. Calcification has occasionally been observed radiographically in a haematoma of very long standing.

In infants the onset occurs during the first year. Enlargement of the head may be the first abnormality to be noticed, but convulsions, irritability, and vomiting are common and pyrexia may be present. The head is found to be enlarged, with a bulging anterior fontanelle and frequently separation of the sutures. The veins of the scalp are often dilated   Papilloedema and retinal haemorrhages are usually present, leading in the later stages to optic atrophy. The symptoms are therefore those of increased intracranial pressure with cortical irritation, and paralysis of the limbs is usually absent. The cerebrospinal fluid may be bloodstained or xanthochromic with considerable excess of protein and is rarely normal. The diagnosis is established by subdural puncture, carried out at the lateral margin of the anterior fontanelle, xanthochromic, or bloodstained fluid being withdrawn from the subdural space.

Diagnosis.

The diagnosis of subdural haematoma offers little difficulty when there is a clear history of recent head injury. In the absence of this the signs of a progressive focal lesion may simulate an intracranial tumour, especially when papilloedema is present. The fluctuating character of the drowsiness and mental confusion, however, may suggest the true diagnosis. In an elderly patient with a history of head injury it may be difficult to distinguish subdural haematoma from a vascular lesion of the brain due to cerebral arteriosclerosis. Indeed, the distinction may be impossible without exploration of the subdural space   Chronic alcoholism in its later stages may lead to mental confusion and drowsiness, and, since it is a predisposing cause of subdural haematoma and may also lead to accidents which involve head injury, may give rise to difficulties in diagnosis. In such cases, again, exploration is likely to be necessary.

Prognosis.

The prognosis of subdural haematoma is very good, provided the diagnosis is made sufficiently early, so that operation can be performed before the patient's general condition has seriously deteriorated. In such cases complete recovery is the rule.

Treatment.

Treatment consists in the surgical evacuation of the blood clot. The fact that the haematoma is bilateral in nearly 50 per cent. of cases must always be borne in mind.

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TRAUMATIC EPILEPSY

Aetiology and Pathology.

Our knowledge of the factors influencing the development of epileptic fits after head injury is mainly derived from observation of cases of gun-shot wound of the head which occurred during the last war. Such injuries are not strictly comparable with the head injuries of civil life, since they include a much higher proportion of penetrating wounds and a much smaller proportion of cases of simple concussion and fracture of the base of the skull.

The frequency with which epilepsy follows head injury has been variously estimated at from 4½ per cent (Sargent) to 25 per cent (Rawling) of cases. Probably under 5 per cent. represents the average incidence.

The latent period between the injury and the onset of fits is extremely variable. In a small proportion of cases fits occur immediately after the injury. These usually cease, and if convulsions subsequently develop they do so only after an interval of freedom. Apart from these early attacks fits may develop within a month or two of the injury, or they may be delayed for as long as ten years In Stevenson's series the longest interval was fourteen years In Wagstaffe's series the average interval was about two years The severity of the injury is important in relation to the likelihood of the development of convulsions. Wagstaffe found that when the injury caused penetration of the dura the incidence of epilepsy was 18 per cent., whereas in all cases of less severe injury it was only 2 per cent. This fact acquires significance from Foerster and Penfield's observation of the part played by scar tissue in the aetiology of traumatic epilepsy. It would appear that epilepsy is most likely to occur when vascularized scar tissue unites the surface of the brain to the dura, and this is obviously most likely to occur when the dura has been penetrated. A family history of epilepsy is sometimes present, so it is probable that inherited predisposition plays a part in the aetiology of traumatic epilepsy in some cases.

Symptoms.

Epileptic attacks following head injury may be focal or generalized. Focal attacks often occur immediately after the injury. Their character and the nature of the aura, if any, depends upon the situation of the lesion. Even when the early attacks are focal there is a tendency for generalized attacks to occur as time goes on. Patients may also suffer from petit mal. For the character of these various forms of attack the reader is referred to the section on epilepsy. When the injury has involved the substance of the cerebral

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hemisphere, corresponding symptoms are likely to be present, and these may be intensified for a short time after each attack. · Radiography, especially ventriculography and encephalography, are often of diagnostic value, since air may fail to reach the area of cortex adherent to the dura and it may be possible to demonstrate a traction
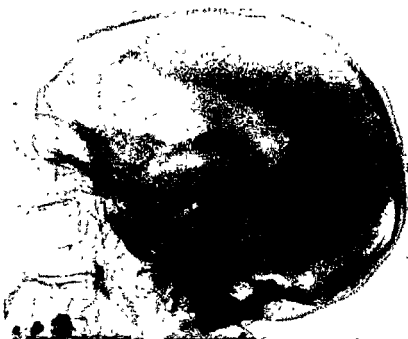
FIG. 40. Ventriculogram showing traction diverticulum in the left frontal region following a fracture. (Radiogram by Dr. Jupe.)

diverticulum, the lateral ventricle, being drawn towards the lesion by the scar (Fig. 40). The electro-encephalogram is normal between the attacks.

Diagnosis.

For the diagnosis of epilepsy see p 864. The traumatic origin of the convulsions can usually only be established when there is a history of injury, and this should be especially inquired for, since the patient may not realize its importance when the attacks do not begin until several years later. It must be remembered that a previous head injury is not necessarily the cause of the attacks, but

its aetiological significance is reinforced if the fits have a focal onset, if there are persistent signs of a focal cerebral lesion, and if the radiographic abnormalities already described are present.

Prognosis.

The factors which influence the prognosis of idiopathic epilepsy apply equally to traumatic cases, but it appears that when a gross focal lesion of the brain is present the prognosis as to recovery is worse than in epilepsy not thus complicated.

Treatment.

Patients with traumatic epilepsy should receive medical treatment *on the same lines as cases of idiopathic epilepsy. Only when this fails* to yield satisfactory results should operation be considered. The surgical treatment of traumatic epilepsy has been carried out for many years, but has fallen into comparative disrepute. Lately, however, it has been revived by Foerster, who claims that by this *method he has obtained a cessation of attacks for a number of years* If it is to be successful the presence of a focal lesion of the brain must be established by the methods already described, and it must be possible to reproduce the attacks by electrical stimulation of the exposed cortex in the affected area. Treatment consists in a free excision of the scar tissue.

Other sequels of head injury, which are described in their respective sections, are meningitis, intracranial abscess, diabetes insipidus, and Parkinsonism.

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3. INTRACRANIAL BIRTH INJURIES

Aetiology and Pathology.

Normal labour involves considerable compression of the foetal head and probably in many cases slight intracranial damage, as is indicated by the presence of red blood-cells in the cerebro-spinal fluid in a proportion of normal newly born infants It is not surprising, therefore, that serious intracranial injury may result from excessive or otherwise abnormal compression due to abnormal presentations or contracted pelvis The most serious intracranial birth injuries are tears of the dura involving rupture of important venous sinuses. As Holland has shown, the most important aetiological factor is excessive longitudinal stress leading to abnormal tension on the falx, which is anchored postero-inferiorly to the tentorium, as a result of which the tentorium may be torn or the vein of Galen ruptured. Large basal haemorrhages occur in such cases. In Holland's series of 157 fresh foetuses the tentorium was torn in 81 (48 per cent.) and the falx in 5. Subdural haemorrhages occurred in all but 6. Over-riding of the parietal bones may lead to rupture of the superior longitudinal sinus or of one or more of its venous tributaries, with the production of a supracortical subdural haemorrhage, which is usually confined to, or predominates upon, one side Abnormal longitudinal stress is most likely to occur in breech presentations, which are, therefore, fraught with special danger to the child. In such presentations, moreover, the thorax may be subjected to considerable compression, thus leading to intracranial venous congestion, oedema, and petechial haemorrhages Prematurity appears to predispose to intracranial haemorrhage, perhaps because the intracranial vessels are more delicate in the premature than in the full-term child. Bilateral subependymal haemorrhages may be found in the lateral ventricles. The Schultze method of resuscitation has been blamed for dural tears. False porencephaly may be a later result of supracortical haemorrhage, and it is possible that some cases of congenital hydrocephalus may be late sequela of intracranial birth injury.

Symptoms.

After a severe intracranial haemorrhage the child may be still-born If it is living it is likely to exhibit 'white asphyxia' due to medullary paralysis. If it recovers from this, it may be cyanosed, breathing slowly and irregularly. The pulse may be slow or rapid and feeble. The child cries feebly and is difficult to feed. Generalized rigidity with head retraction is common, and local or general con-

vulsions may occur. A supracortical haemorrhage is likely to lead to hemiplegia. Papilloedema and retinal haemorrhages may be present, and in some cases exophthalmos, inequality of the pupils, squint, and nystagmus occur. The fontanelles may be bulging and non-pulsating. The cerebro-spinal fluid is likely to be blood-stained and under increased pressure, and when the haemorrhage is supra-cortical it may be possible to withdraw blood by subdural puncture at the lateral angle of the anterior fontanelle.

In some cases the signs of injury are absent at birth but develop gradually in the course of the first four or five days.

Diagnosis.

There is usually little doubt about the diagnosis, though occa-sionally intracranial injury may be suspected in a child suffering from congenital diplegia. In the latter condition, however, local or general microcephaly is not uncommon; the fontanelle will not bulge, and the cerebro-spinal fluid is likely to be normal.

Prognosis.

In the majority of cases in which the symptoms are sufficiently severe to enable an intracranial birth injury to be diagnosed, death occurs if not before or immediately after birth, within three or four days. Infants which survive may suffer from infantile hemiplegia, epilepsy, mental defect, or congenital hydrocephalus. Pachymenin-gitis interna haemorrhagica of infants is regarded by some as a sequel of intracranial birth injury. Congenital diplegia is probably only very rarely thus produced.

Treatment.

In mild cases lumbar puncture may be used to lower the intra-cranial pressure. In severe cases it probably does more harm than good. When the symptoms indicate the presence of a supracortical haemorrhage an attempt may be made to remove some of the blood by subdural puncture through the lateral angle of the anterior fontanelle or by craniotomy.

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CHAPTER VI

DISEASES OF THE MENINGES

I THE ANATOMY OF THE MENINGES

The brain and spinal cord are covered by three membranes or meninges named, from without inwards, the dura mater, the arachnoid, and the pia mater.

The *Dura Mater* is thick and fibrous and serves as the internal periosteum of the bones of the skull, to which it is closely applied. The inner surface is covered with a layer of endothelial cells. Sheaths of dura mater extend outwards for a short distance as a covering for the cranial nerves as they pass through their respective foramina. Certain fibrous processes of the dura, or septa, partially separate the cranial cavity into compartments. These are the falx, the tentorium, the falx cerebelli, and the diaphragma sellae. The falx descends from the cranial vault in the middle line lying between the cerebral hemispheres in the great longitudinal fissure. It is attached anteriorly to the crista galli and posteriorly to the tentorium. At its superior attached border it splits into two layers to contain the superior longitudinal sinus, and its lower free border similarly splits to contain the inferior longitudinal sinus. The tentorium cerebelli forms a partition between the posterior and middle fossae of the skull, its free border surrounding the midbrain and its attached border being fixed to the occipital and parietal bones and to the superior border of the petrous portion of the temporal bone. The posterior part of its attached border splits to enclose the lateral sinus, and the anterior part similarly encloses the superior petrosal sinus. The falx cerebelli lies in the middle line between the tentorium and the internal occipital crest, to both of which it is attached, and its free border separates the cerebellar hemispheres posteriorly. The diaphragma sellae forms a roof to the sella turcica and contains an opening, through which passes the infundibulum.

The *Pia Mater* is a delicate membrane lined with endothelial cells, which intimately clothes the surface of the brain, dipping into the sulci.

The *Arachnoid* is a similar membrane, lying between the dura mater and the pia mater and bridging over the sulci. The space between the arachnoid and the pia mater, which is known as the subarachnoid space, contains the cerebro-spinal fluid. Its expansions are known as the subarachnoid cisterns. The cisterna magna lies between the inferior surface of the cerebellum and the posterior surface of the medulla. The cisterna pontis, continuous with this,

lies anteriorly to the pons and is continued upwards into the cisterna interpeduncularis This in turn is continued forwards into a cistern lying in front of the optic chiasma—the cisterna chiasmatis The subarachnoid space and its continuations into the substance of the nervous system—the perivascular spaces—have been described in the section on the cerebro-spinal fluid (p 108). Between the dura mater and the arachnoid lies a potential space, the subdural space.

The spinal meninges are described in the section on the anatomy of the spinal cord (p. 601).

The dura mater is known as the pachymeninx, the arachnoid and the pia mater as the leptomeninges Hence infection of the dura mater is described as pachymeningitis, and infection of the pia and arachnoid as leptomeningitis or simply as meningitis.

2. TUMOURS OF THE MENINGES

3. CALCIFICATION OF THE FALX

Calcification of the falx is usually discovered accidentally in the routine radiographic examination of the skull. It is best seen in postero-anterior radiograms as a well-defined linear opacity in the middle-line. The calcification is much less evident in lateral radiograms, in which it appears as scattered opaque flecks, most evident immediately above the crista galli and extending backwards for a variable distance Little is known as to the cause of the calcification, but it has been suggested that it is the outcome of a low-grade chronic infection. I have observed it in two cases of cerebral syphilis, but usually the cause is not obvious. It is uncertain whether it causes symptoms, though headache has been ascribed to it. Its association with epilepsy appears too frequent to be fortuitous.

4. PACHYMENINGITIS

SYPHILITIC PACHYMENINGITIS

PYOGENIC PACHYMENINGITIS

Infection of the dura mater with pyogenic organisms is usually secondary to pyogenic cranial osteitis. The symptoms and treatment are those of subdural abscess (p. 374).

PACHYMENINGITIS INTERNA HAEMORRHAGICA

5. ACUTE LEPTOMENINGITIS

Definition. Acute inflammation of the leptomeninges

Aetiology.

Infection may reach the leptomeninges by the following routes:

(1) *Direct spread from without.* This may occur as a result of fracture of the skull, either in the case of penetrating wounds of the cranial vault or fractures of the base, when organisms may spread to the meninges from the nasopharynx. In the latter case the fracture may be unsuspected until meningitis develops. Other external sources of meningitis are osteitis of the cranial bones, especially mastoiditis, infection of the nasal air sinuses, especially the frontal sinus, and of the soft tissues of the scalp, and thrombophlebitis of the intracranial venous sinuses.

(2) *Direct spread from within* may occur when the meninges are infected secondarily to an intracranial abscess of embolic origin or in tuberculous meningitis secondary to a cerebral tuberculoma.

(3) *Infection through the Blood-stream.* In such cases meningitis follows bacteraemia. It may be the only or the principal manifestation of this, as in so-called 'primary' pneumococcal meningitis and in meningococcal meningitis, of which chronic posterior basic meningitis is a form, or the infection of the meninges may be secondary to focal infection elsewhere in the body, for example, pneumonia, empyema, osteomyelitis, erysipelas, enteric fever, &c., in which case the bacteraemia may or may not be associated with endocarditis due to the infecting organism. Tuberculous meningitis may thus be part of a general miliary dissemination of tuberculosis.

(4) *Meningitis complicating Encephalitis and Myelitis.* Meningeal inflammation often plays a subordinate part in the picture of encephalitis or myelitis. Acute anterior poliomyelitis is the best example of such a meningo encephalo-myelitis, and meningeal inflammation similarly occurs in herpes zoster. In such conditions meningeal symptoms may be prominent or slight, but the cerebro-spinal fluid yields evidence of meningeal inflammation.

(5) *Other forms of Meningitis.* Subarachnoid haemorrhage excites an inflammatory reaction in the leptomeninges, though organisms are absent. Toxic irritation of the meninges also plays a part in acute lead encephalopathy. Occasionally in cases of meningitis no source of infection is found and no organisms are cultivated from the cerebro-spinal fluid. This condition is known as 'acute aseptic meningitis' The term 'serous meningitis' possesses no constant

meaning. It has been applied to at least two groups of cases.
(1) meningitis associated with a cranial focus of infection, for
example mastoiditis, without the passage of organisms into the
cerebro-spinal fluid, and (2) hydrocephalus, probably due to defective
absorption of cerebro spinal fluid and not uncommonly a late result
of mastoiditis or otitis media 'Meningism' occurs as a complication
of acute infections, especially in childhood. Symptoms of meningeal
irritation are associated with a rise in the pressure of the cerebro-
spinal fluid. This is secondary to dilution of the blood as a result of
which the pressure of the cerebro-spinal fluid is increased while its
chloride and protein content fall.

Spinal meningitis, that is, meningitis arising in, and at first limited
to, the spinal canal, is rare and is usually secondary to osteitis of the
vertebral column.

The following organisms are those commonly responsible for
meningitis. The meningococcus is the cause of epidemic cerebro-
spinal meningitis and also of sporadic cases. The pneumococcus may
cause 'primary' meningitis, meningitis complicating pulmonary and
pleural infections, infections of the nasal air sinuses and middle ear,
and meningitis following fracture of the base of the skull The
streptococcus, and less often the staphylococcus, are responsible for
meningitis following trauma and cranial osteitis and occurring in
various pyaemic states The tubercle bacillus is responsible for tuber-
culous meningitis ; and the spirochaeta pallida, when it invades the
nervous system, causes meningeal inflammation varying in acuteness
and severity. A filtrable virus is the cause of acute lymphocytic
chorio-meningitis. Other organisms less frequently the cause of
meningitis are *B. typhosus, coli, enteritidis, dysenteriae, influenzae,
anthracis, abortus*, the *gonococcus*, the viruses of mumps, psitta-
cosis and infectious mononucleosis, *streptothrix, leptothrix*, the spiro-
chaete of Weil's disease, and yeasts, such as *torula*. Mixed infections
may occur.

It is convenient to classify acute meningitis as follows:

(1) Acute pyogenic meningitis, due to the streptococcus, pneumo-
coccus, staphylococcus, and pyogenic organisms other than the
meningococcus.

(2) Meningococcal meningitis.

(3) Acute lymphocytic chorio-meningitis and acute aseptic menin-
gitis

(4) Tuberculous meningitis.

(5) Meningitis due to torula.

(6) Spinal meningitis.

ACUTE PYOGENIC MENINGITIS

(other than Meningococcal Meningitis)

Pathology.

Whatever the causative organism the pathological changes in acute pyogenic meningitis are similar in all cases. Whether the organism reaches the meninges by direct spread or through the bloodstream, inflammation and its products become rapidly diffused through the whole subarachnoid space of the brain and spinal cord. The space between the pia mater and the arachnoid membranes becomes filled with greenish-yellow pus, which may cover the whole cerebral cortex or may be occasionally confined to the sulci. In cases of cranial osteitis and cerebral abscess the pus may be most evident near the source of the infection. The cortical veins are congested, and the convolutions are often flattened owing to internal hydrocephalus. Microscopically the leptomeninges show inflammatory infiltration which in the early stages consists wholly of polymorphonuclear cells, though in the later stages lymphocytes and plasma cells are present. The cerebral hemispheres show little change except for pervascular inflammatory infiltration of the cortex. In chronic posterior basic meningitis the inflammation is confined to the base of the brain and consists of chronic thickening of the pia arachnoid with adhesions but little or no exudation. Internal hydrocephalus is a common and important complication of acute meningitis. It is most often due to inflammatory adhesions in the cisterna magna, obstructing the outflow of cerebro-spinal fluid from the fourth ventricle. Another factor in the production of hydrocephalus is the obstruction offered by the inflammatory exudate to the upward passage of the cerebro-spinal fluid over the hemispheres and impairment of its absorption by blockage of the arachnoid villi with inflammatory products. In meningitis the infection may spread to the optic nerves, causing true optic neuritis apart from the papilloedema due to raised intracranial pressure, and to the internal ear, sometimes causing permanent deafness.

Symptoms.

All forms of acute meningitis, whatever their cause, possess a number of symptoms in common. The onset extends over one to three days. Headache, increasing in severity, is usually the initial symptom.

The general symptoms of an infection are usually conspicuous. Fever is the rule, though the degree of pyrexia varies. The temperature is usually between 100° and 102°, though hyperpyrexia may occur, especially in the terminal stages. The pulse-rate is also

variable. It is sometimes slow in the early stages, for example between 50 and 60, but always rises as the disease progresses and at the end is usually very rapid and often irregular. The respiratory rate is usually slightly increased, and various forms of irregularity of respiration, especially Cheyne-Stokes breathing, occur in the later stages. Headache is a prominent symptom and is usually very severe, possessing a 'bursting' character. It may be diffuse or mainly frontal, and usually radiates down the neck and into the back, being associated with pain in the spine which radiates to the limbs, especially to the lower limbs. Vomiting may occur, especially in the early stages. Convulsions are common in children but rare in adults. The patient tends to lie in an attitude of general flexion, curled up under the bed-clothes and resenting interference.

Signs of Meningeal Irritation.

The following signs are of special value as indicating meningeal irritation.

Cervical Rigidity. Cervical rigidity is present at an early stage in almost every case of meningitis. It is elicited by the observer's placing his hand beneath the patient's occiput and endeavouring to cause passive flexion of the head so as to bring the chin towards the chest. In a normal individual this can be accomplished with ease and without pain. In meningitis there is a resistance due to spasm of the extensor muscles of the neck, and an attempt to overcome this causes pain.

Head Retraction is an extreme degree of cervical rigidity brought about by spasm of the extensor muscles, but it should be noted that cervical rigidity may be demonstrable by the observer before head retraction has developed. Flexion of the neck causes a rise in the tension of the cerebro-spinal fluid in the cisterna magna. When the meninges are inflamed this is painful, and cervical rigidity and head retraction are examples of reflex spasm of a protective character. Cervical rigidity is usually associated with some rigidity of the spine at lower levels.

Kernig's Sign. Kernig's sign, though slightly less frequently encountered in meningitis than cervical rigidity, is of a somewhat similar nature. An attempt to produce passive extension of the knee with the hip fully flexed evokes spasm of the hamstrings and causes pain. This procedure causes stretching of the spinal nerve-roots passing to the lower limb and is painful when the lower end of the subarachnoid space of the spinal cord is distended and the lepto-meninges are inflamed.

Brudzinski's Signs. Brudzinski's signs are present in meningitis with a frequency somewhat less than that of Kernig's sign. They are:

(1) *The identical contra-lateral reflex.* On passive flexion of one thigh and leg a similar movement occurs spontaneously in the opposite lower limb.

(2) *The reciprocal contra-lateral reflex.* On relaxing one lower limb after passive flexion, flexion of the opposite lower limb occurs.

(3) *The neck sign.* On passive flexion of the neck, flexion at the hips and knees occurs.

Other Signs

The mental state of the patient varies according to the stage and progress of the disease. Delirium is common in the early stages, but tends when the disease is progressive to give place to drowsiness and stupor, which is followed by coma. Photophobia is frequently present and there is a general hyperaesthesia to all forms of stimuli. The ocular fundi may be normal or may show venous congestion or papilloedema. The last is inconstant. The pupils are often unequal and may react sluggishly. In the later stages they tend to be dilated and fixed. Ptosis is common, and squint and diplopia are often present. Any of the ocular muscles may be paralysed, most frequently one or both external recti. Facial paresis is not rare. Difficulty in swallowing may occur in the later stages. Muscular power in the limbs is usually well preserved, though slight in-co-ordination and tremor are common and there is considerable muscular hypotonia. A general flaccid paralysis is a terminal event. The tendon reflexes are usually sluggish and often are soon lost; the abdominal reflexes also disappear early; the plantar reflexes are usually flexor at first, though later one or both may become extensor. Sensory loss does not usually occur. True paralysis of sphincter control occurs only late, but the mental state of the patient may lead to retention or incontinence of urine early in the illness and constipation is the rule. Tâche cérébrale is often elicitable, but is not pathognomonic of meningitis.

Meningitis localized for a time to one hemisphere may cause Jacksonian convulsions, hemiparesis and even hemianopia.

The Cerebro-spinal Fluid.

The cerebro-spinal fluid is under increased pressure. Its appearance depends upon the number of leucocytes present, and ranges from slight turbidity to frank purulence. When the fluid is turbid the deposit is yellow, and when macroscopical pus is present the supernatant fluid is frequently xanthochromic. The spontaneous formation of a fine coagulum is not uncommon. The cells are predominantly polymorphonuclear and these may be present in very large numbers, amounting to many thousands per c mm. There is fre-

quently a small proportion of large mononuclear cells. The protein is increased, and in frankly purulent fluids may reach a high level—65 per cent or more. The chloride content of the fluid is reduced to 550 to 680 mg per 100 c.c. on an average. Glucose rapidly disappears from the fluid. Lange's colloidal gold curve is of the meningitic type. Organisms may be demonstrated in the films or on culture, but may be absent in cases of localized inflammation of the meninges. Filterable viruses require special methods to demonstrate them.

Diagnosis.

Acute pyogenic leptomeningitis must be distinguished from (1) general infections associated with toxaemia, especially those of which headache is a prominent symptom, (2) meningism, (3) acute cerebral infections, including various forms of encephalitis and intracranial abscess, (4) other forms of meningitis and meningeal irritation.

(1) *Acute general infections* which most commonly simulate meningitis are influenza, pneumonia, typhoid fever, and acute rheumatism. These are distinguished from meningitis by the presence of the characteristic local and general symptoms of the infection and by the absence of signs of meningeal irritation, especially cervical rigidity and Kernig's sign. It must be remembered, however, that acute infections may lead to meningism or may be complicated by meningitis, and in either case signs of meningeal irritation will be present. When the diagnosis is in doubt, therefore, lumbar puncture should be performed.

(2) *Meningism* is a state of meningeal irritation complicating acute infections. It is usually encountered in association with the acute specific fevers and pneumonia in childhood. Cervical rigidity and Kernig's sign are present, but the cerebro-spinal fluid, though under increased pressure, is normal in composition except for a low chloride and protein content.

(3) *Encephalitis lethargica* is rarely associated with symptoms of meningeal irritation. These, however, are much more frequently present in the *acute meningo-encephalo-myelitis* of childhood and in *acute disseminated encephalo-myelitis* complicating the specific fevers, and are almost constant in the early stages of *acute polio-myelitis*. The diagnosis of these disorders is based upon the presence of signs of involvement of the nervous system, especially the grey matter of the midbrain in encephalitis lethargica and of the pyramidal tracts in the various forms of acute disseminated encephalo-myelitis. In acute poliomyelitis the stage of meningeal irritation precedes the development of atrophic paralysis. In encephalitis lethargica and acute disseminated encephalo-myelitis the cerebro-spinal fluid is not

uncommonly normal, and when a leucocytosis is present the cells are mononuclear. In acute poliomyelitis the cerebro-spinal fluid contains an excess of cells, which during the first few days consist of both polymorphonuclear cells and lymphocytes. After the first week lymphocytes alone are found. The presence of large numbers of lymphocytes and of a normal glucose content of the fluid differentiates the condition from acute pyogenic leptomeningitis, and the normal chloride content distinguishes it from tuberculous meningitis. *Intracranial abscess* may simulate meningitis when it gives rise to cervical rigidity, which, however, is usually not severe unless meningitis co-exists. In cases of intracranial abscess the cerebro-spinal fluid usually contains an excess of cells, though not often more than 100 per c mm., the majority being lymphocytes. The chloride and sugar content of the fluid are undiminished and organisms are absent.

(4) *Subarachnoid haemorrhage*, since it leads to meningeal irritation, may closely simulate meningitis. Its onset, however, is usually more rapid, and the true diagnosis is readily established by the demonstration of blood in the cerebro-spinal fluid. A localized meningitis. sometimes called *serous meningitis*, may occur as a complication of pyogenic infection in the neighbourhood of the meninges, especially of mastoiditis, subdural abscess, and lateral sinus thrombosis. In such cases the cerebro-spinal fluid is usually under increased pressure and exhibits a slight excess of cells, which may be either polymorphonuclear, mononuclear, or mixed. Organisms are absent. *Meningococcal meningitis* is to be suspected in cases of acute meningitis when no focal source of the infection can be discovered. The presence of the characteristic rash affords confirmatory evidence, but the nature of the causative organism in meningococcal, as in other forms of pyogenic meningitis, can be established only by its demonstration in the cerebro-spinal fluid. *Acute lymphocytic choriomeningitis* should be suspected in cases of meningitis of acute onset running a benign course and in which no focal source of the infection can be detected and organisms cannot be demonstrated in the cerebro-spinal fluid on repeated examination by ordinary methods. *Tuberculous meningitis* usually develops much more insidiously than meningitis due to pyogenic organisms, and symptoms of meningeal irritation, for example cervical rigidity and Kernig's sign, are often slight and may be absent. The cerebro-spinal fluid contains an excess of cells, consisting usually of polymorphonuclear and mononuclear cells in varying proportions. The chloride content of the fluid is subnormal and reaches a lower figure than occurs in pyogenic meningitis, the average being 510 mg. per 100 c.c. Tubercle bacilli may be demonstrable in the fluid. *Syphilitic meningitis* is occasionally sufficiently acute to lead to confusion with pyogenic meningitis.

In such cases the cerebro-spinal fluid contains an excess of cells which are usually mononuclear, but in the most acute cases polymorphonuclear cells may also be present. The Wassermann reaction is usually positive in the fluid and also in the blood.

Prognosis.

The prognosis of acute pyogenic leptomeningitis depends upon the nature of the invading organism, the number of organisms present in the cerebro-spinal fluid, the possibility of removing the source of infection, and the effectiveness of bactericidal drugs. The introduction of the sulphanilamide group of drugs which pass readily into the cerebro-spinal fluid and exert a strong bactericidal action there, promises to revolutionize the prognosis of many forms of meningitis In the past pneumococcal meningitis was almost invariably fatal and streptococcal meningitis was fatal in more than 90 per cent. of cases Already recoveries from the former are being reported and the mortality rate of the latter is being reduced. Examination of the cerebro-spinal fluid is important in estimating the prognosis. When polymorphonuclear cells are few and organisms are absent the outlook is good, since a cerebro-spinal fluid of this type usually means a localized meningitis. A patient may survive recurrent attacks of localized meningitis secondary to chronic otitis.

Treatment.

The patient must be kept in bed in a darkened room and should receive concentrated liquid nourishment. Nasal feeding will be necessary if swallowing is difficult An ice-pack to the head may relieve headache. Sedatives will usually be required When meningitis is due to the extension to the meninges of infection from one of the cranial bones, for example frontal sinusitis, otitis media, or mastoiditis, the source of infection requires immediate surgical treatment. Lumbar puncture not only relieves headache but is a method of draining the subarachnoid space of organisms and the products of infection. It should be repeated twice or thrice daily, the pressure of the cerebro-spinal fluid being reduced to normal on each occasion. If the patient can be kept in one position, continuous drainage of the subarachnoid space can be carried out by keeping the lumbar puncture needle in position for several hours, at the same time giving large quantities of water by the mouth or of hypotonic (half normal) saline subcutaneously, in order to increase the production of cerebro-spinal fluid.

It has yet to be determined which drugs of the sulphanilamide group are the most useful. Prontosil has been used successfully for meningococcal, streptococcal, B. coli, and pneumococcal meningitis.

A A

Pneumococcal meningitis has also been successfully treated with sulphapyridine. Staphylococcal infections have been treated with both.

The standard dose for oral administration is 1 gm. daily per stone of body weight, but infants require twice or three times this dose. The drug is given at four-hourly intervals. After three days the dose is gradually reduced, but administration is continued for about nine days in all. Alternatively an initial dose of 1·5-2·5 gm. of sulphapyridine may be given intramuscularly in a suspension of 0·5 gm to 5 c.c. of saline, a second smaller dose being given if necessary.

MENINGOCOCCAL MENINGITIS

Definition: An infection of the leptomeninges forming part of a general infection with the meningococcus.

Synonyms: Cerebro-spinal meningitis; cerebro-spinal fever; spotted fever.

Aetiology.

The causal organism is the meningococcus or 'diplococcus intracellularis meningitidis' of Weichselbaum. This is a kidney-bean-shaped Gram-negative coccus which is found usually in pairs, but occasionally in tetrads, in the exudation from the meninges, and in the cerebro-spinal fluid, where it may be enclosed in polymorphonuclear leucocytes or free. The meningococcus is usually obtainable from the secretions of the eyes, nose, and pharynx of both patients and 'carriers', and in the early stages of the infection it can often be isolated from the patient's blood. Gordon in 1917, by means of agglutination tests, succeeded in separating meningococci into groups—1, 2, 3, and 4. This made it possible to identify the organism responsible for a particular epidemic and to produce specific immune sera At present, however, the 'typing' of meningococci is not entirely satisfactory. Other classifications have been proposed, and intermediate types identified. A polyvalent serum is usually employed in treatment.

Meningococcal meningitis occurs both in epidemics and sporadically. It is a disease of the temperate zone, and the period of epidemic prevalence is the winter and spring. Epidemics usually begin in December and reach their height in April and May, the number of cases thereafter diminishing, to cease in July. Sporadic cases occur at any time of year.

The disease, although contagious, is only slightly so, and it is exceptional for multiple cases to occur in a single household or for the infection to spread in hospital. The disease is spread by droplet infection, mainly through the agency of 'carriers'. These are usually

individuals who have been in contact with a patient and who harbour the meningococcus in the nasopharynx for a period which usually lasts only two or three weeks. Such 'carriers' who greatly outnumber overt cases may infect other persons without themselves developing the disease, or after a period of apparently good health may develop meningitis The principal predisposing cause of epidemics is overcrowding, and the disease is thus specially prevalent among children, who come into close contact with each other at school, and soldiers, who are crowded together in barracks. There is some evidence that catarrhal disorders of the nose and throat predispose to the infection Both sexes are affected with equal frequency, and the age of greatest susceptibility is from infancy to ten years. The disease is rare after the age of 40. The incubation period varies from one to seven days and is usually about four days.

The route by which the meningococci, having been implanted in the nasopharynx, reach the meninges is still unsettled. Probably they are carried by the blood-stream, though direct spread along the lymphatics of the olfactory nerves cannot be excluded.

Pathology.

See p. 348

Symptoms.

Mode of Onset.

The onset is usually acute, headache, fever, with chills or actual rigors, and signs of meningeal irritation developing within the first twenty-four hours Less frequently it is gradual, and still less frequently a fulminating onset occurs, the patient passing into coma within a few hours Convulsions are common in children, but rare in adults. Constipation is the rule, but diarrhoea may occur, especially in children, and may be associated with abdominal pain. Fever is present, but the temperature varies. It is usually between 100° and 102° F., but hyperpyrexia may occur, especially as a terminal event. The pulse is also variable. It is usually somewhat slow in proportion to the temperature and an actual bradycardia may occur, especially in the early stages. The patient looks ill and may be flushed or pale and usually lies in an attitude of general flexion and resents interference.

Nervous Symptoms.

Headache is severe and radiates down the neck, being associated with pains in the spine and often also in the limbs. Vomiting often occurs, especially during the first two days. Delirium is common after the first twenty-four hours and in severe cases passes into

stupor and finally into coma. Signs of meningeal irritation are conspicuous; cervical rigidity, Kernig's sign, and Brudzinski's signs are usually elicitable within the first twenty-four hours. Later actual head retraction occurs (Fig. 41), which may develop, especially in young children, into opisthotonos. The optic disks may be normal or exhibit some venous congestion. Papilloedema is present in only a minority of cases. The pupils are usually slightly dilated
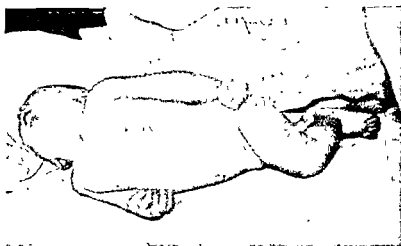
FIG 41 Head retraction in a case of meningococcal meningitis.

and may react sluggishly. Slight ptosis and a divergent squint are common. Paresis of ocular muscles, especially the external rectus, may occur, and diplopia is a frequent complaint. Trismus is rare, but sometimes occurs. Facial paresis is often observed. There is usually no marked loss of power in the limbs, except that flaccid paralysis may supervene in the terminal stages. Tremor, however, is common The tendon and abdominal reflexes are usually diminished, and the plantar reflexes, though flexor at first, may later become extensor. Loss of sphincter control is usually the outcome of the mental state of the patient. Retention of urine, with overflow, and incontinence of faeces are likely to occur during delirium and stupor There is no characteristic sensory loss General hyperaesthesia is often present, but photophobia is less frequent than in tuberculous meningitis. Some degree of hydrocephalus is frequently present and leads to bulging of the anterior fontanelle in infancy and to congestion of the veins of the scalp, a symptom which is more conspicuous in children than in adults.

The Skin.

Several types of rash may occur, the most characteristic being a purpuric eruption which may take the form of petechiae, which are purple at first, fading to a brownish colour, and do not disappear on pressure They are especially liable to occur on regions subjected to pressure. The purpuric patches may be larger, even reaching the size of half a crown, but these are found only in very severe cases The purpuric eruption may appear during the first twenty-four hours and is usually present before the third day. It is seen in about one-third of all cases. A maculopapular rash is present somewhat less frequently, usually appearing before the fourth day, first on the trunk and later on the extensor surfaces of the thighs and forearms Erythematous rashes may occur at any stage of the disease, and facial herpes febrilis appears in between 20 and 30 per cent of cases

The Blood.

A well-marked leucocytosis occurs in the blood, with a predominant increase of the polymorphonuclear cells Meningococci can sometimes be cultivated from the blood in the early stages, but rarely after the signs of meningitis have appeared.

The Cerebro-spinal Fluid.

Pressure. The pressure of the cerebro-spinal fluid is increased from the beginning, being on an average about 300 mm of fluid, though it may sometimes be as high as 1,000 mm. After internal hydrocephalus has supervened, or when communication between the cisterna magna and the spinal subarachnoid space is obliterated by adhesions, the pressure is likely to be subnormal.

Quantity. It is usually possible to withdraw much larger quantities of fluid than is normally the case, namely from 30 to 60 c.c In the two cases just described, however, a dry tap may occur.

Appearance. During the first twenty-four hours the fluid may be clear. Usually, however, it is turbid and may later become purulent, which it occasionally is from the beginning. After the intrathecal administration of serum a fluid previously turbid is likely to become purulent. In the case of a purulent fluid, after the pus has settled the supernatant fluid is usually yellow in colour.

Protein. The protein is increased, being usually between 0·1 and 0·4 per cent. The globulin also is increased. Fibrinogen is often present, as indicated by the formation of a cobweb clot on standing. When the fluid is highly albuminous spontaneous coagulation may occur

Cells. There is a marked increase in the cell content of the fluid, the predominating cell being the polymorphonuclear, of which 1,000

to 2,000 per c.mm. are usually present. There is also an increase in the mononuclear cells, though not to the same extent. The number of these tends to increase as time goes on. In fulminating cases the cell content of the fluid may be comparatively low.

Meningococci. Meningococci can be demonstrated in the fluid in from 90 to 100 per cent. of cases. Usually they are present in smears made from the centrifuged deposit on the day of withdrawal. The majority of meningococci are usually intracellular, lying within the polymorphonuclear leucocytes. Some, however, are extracellular, and a large number of extracellular meningococci is believed to be indicative of a severe infection. If meningococci are not demonstrable on the first day they are usually to be found if the fluid be incubated for twenty-four hours, or may be obtained from cultures.

In the past, type 2 meningococcus has been most frequently encountered in this country, but at present the typing of the organism is not entirely satisfactory.

Glucose. The glucose content of the cerebro spinal fluid is always greatly reduced, and glucose may disappear from the fluid entirely. It is probably destroyed by the organisms, since it may be almost normal in pyogenic meningitis when organisms are absent from the fluid.

Chlorides The chloride content of the fluid is usually somewhat reduced and lies between 650 and 680 mg. per 100 c.c. It is rarely below 600 mg.

Colloidal Gold Curve. The colloidal gold curve is of the meningitic type.

Ventricular Fluid. It is desirable to examine the cerebro-spinal fluid from the cerebral ventricles if internal hydrocephalus develops or if, in spite of improvement in the condition of the spinal fluid, symptoms of infection persist, since the demonstration of meningococci in the ventricular fluid calls for the intraventricular injection of antimeningococcal serum.

Other Symptoms.

Slight cardiac dilatation may occur as a result of the toxaemia, the cardiac apex being displaced outwards and the apical first sound soft or muffled. Albuminuria may also occur as in other febrile conditions. A catarrhal inflammation of the upper respiratory tract is also common. Rapid flushing of the skin in response to a light scratch, the symptom known as 'tâche cérébrale', is often present, but is not pathognomonic of meningitis.

Complications of Meningococcal Origin.

The symptoms already described are those attributable to the meningitis and the bacteriaemia which precedes it. We may describe

as complications manifestations of the infection which are inconstant and in some instances rare.

Internal Hydrocephalus. Internal hydrocephalus is the most important complication of meningococcal meningitis It usually develops late in the course of the disease, rarely during the first two weeks. Its onset is associated with an intensification of the headache, and with persistent vomiting. The mental condition of the patient deteriorates and he becomes drowsy and listless. Memory is impaired. Convulsions may occur. Vision deteriorates, but papilloedema is usually absent. The optic disks may be normal, or may show atrophy of the primary type. The loss of vision is probably due in part to downward pressure of the floor of the third ventricle upon the optic chiasma and in part to compression of the optic radiations and visual cortex by distension of the posterior horns of the lateral ventricles. The pupils are often dilated and react sluggishly to light Ocular palsies are often present, the external rectus muscle being most frequently paralysed. Nystagmus is common and exophthalmos may occur. The limbs become progressively weaker and more tremulous and tend to be spastic with exaggerated tendon reflexes, and in some cases extensor plantar responses are present. The rise in intracranial pressure leads in infants to bulging of the anterior fontanelle and sometimes to separation of the cranial sutures, which may occur in older children also. The skull may yield a 'cracked-pot sound' on percussion.

Other Nervous Complications Symptoms due to invasion of the nervous system by the infection, or vascular lesions such as thrombosis, are uncommon. Aphasia and hemiplegia are sometimes met with and indicate damage to the cerebral hemispheres, while lesions of the spinal cord may cause paraplegia or flaccid paralysis with wasting of a group of muscles. Peripheral neuritis, usually affecting the lower limbs, sometimes occurs.

Deafness. Deafness is the most frequent of the severe complications. It usually begins early in the illness and may be temporary, but is more often permanent, both ears being usually affected. It is uncertain whether it is due to a lesion of the eighth nerve or to spread of infection to the internal ear. In cases of permanent deafness the labyrinthine functions usually remain normal.

The Eye. Conjunctivitis is a fairly common complication. More severe ocular lesions, such as *keratitis* and *iridochoroiditis*, are fortunately rare. Loss of vision as a result of internal hydrocephalus has been described above.

The Heart. Fibrino-purulent pericarditis is a rare complication of severe cases. Ulcerative endocarditis is even rarer. When this develops, embolism of the lungs or other parts of the body may occur.

Arthritis occurs in from 10 to 15 per cent. of cases in most epidemics. There is a purulent effusion into the joint, from which meningococci can occasionally be cultivated. The knee- and shoulder-joints are most frequently affected, but almost any joint may become involved.

Genito-urinary System. Febrile albuminuria is common. Rarely a true acute nephritis develops, often with haematuria. This is probably due to the meningococcal infection. Pyelitis and cystitis are also sometimes encountered. Epididymitis and orchitis are rare complications.

Non-Meningococcal Complications.

Though pneumonia may very rarely be due to the meningococcus, it is more often the result of a secondary infection. Broncho-pneumonia is the form usually encountered and is a serious complication. Infection of the urinary tract, usually with *Bacillus coli*, may occur, especially when frequent catheterization is necessary. It may be difficult to prevent the development of bed sores in very chronic cases

Clinical Types

The recognition of clinical types of such a disease as meningococcal meningitis is to some extent artificial and can be multiplied to almost any degree Nevertheless, it is valuable to recognize that various forms of the disease occur, depending mainly upon the acuteness and course of the infection.

The Fulminating Type. In this form the onset is extremely sudden and symptoms of a profound toxaemia rapidly make their appearance The patient may become comatose a few hours after the onset and die on the first or second day. The meningeal symptoms may be to some extent masked by the toxaemia, and the polymorpho-nuclear leucocytosis in the cerebro-spinal fluid may be comparatively slight.

The Acute Type. This is the acute form of the disease frequently encountered. The onset is usually sudden and delirium is usually present by the second day, the patient often being noisy and restless when he first comes under observation.

In *Sub-acute Cases* the onset is often more gradual and both the meningeal and general symptoms are less severe.

Abortive Cases occur in which symptoms of meningitis develop acutely and rapidly subside.

The term *Chronic Type* has been used to describe cases in which, after beginning acutely or subacutely, the disease runs a chronic course lasting weeks or even months. In these cases hydrocephalus is usually present.

Chronic Posterior Basic Meningitis is a chronic form of meningococcal meningitis occurring in infants, usually between the ages of 4 months and $2\frac{1}{2}$ years The onset is usually acute with fever, which, however, tends to subside at the end of the first week Head retraction is usually well marked and may be associated with opisthotonos Hydrocephalus develops early, and the later symptoms are similar to those already described under this heading.

Onset with Prolonged Septicæmia This is a rare but important form of the disease in which the patient suffers from septicæmia proved by blood culture to be due to the meningococcus and persisting in some cases for weeks without meningitis developing Such cases may terminate in meningitis or recovery may even occur without any infection of the meninges The characteristic symptoms are intermittent fever, joint pains, and a papular (rarely purpuric) rash.

Diagnosis.

See p. 351.

Prognosis.

The mortality rate varies in different epidemics and even in different stages of the same epidemic, being usually highest at the beginning It is higher in cases occurring during epidemics than in sporadic cases and is highest in infancy and old age. Before the introduction of serum treatment the mortality rate ranged from 40 to 90 per cent. in different epidemics The use of immune serum has reduced this to from 10 to 30 per cent in some epidemics. The introduction of the sulphanilamide group of drugs has reduced it much further.

Clinical points which are of bad prognostic import include the rapid development of coma, severe delirium, and purpura. Repeated examination of the cerebro-spinal fluid affords useful information as to the probable outcome. The presence of large numbers of meningococci in the fluid at the onset is said to indicate a severe attack, while their rapid disappearance in response to treatment, together with a diminution in the number of polymorphonuclear cells and in the amount of albumin, an increase in the number of lymphocytes, and the reappearance of sugar are favourable signs.

The employment of sulphanilamide has done much to shorten the course of the disorder and to reduce the risk of sequels. Chronic cases are uncommon. Mental deficiency, epilepsy, blindness, and incoordination and spastic weakness of the limbs are not uncommon sequels in patients who have survived the infection but have been left with some degree of chronic internal hydrocephalus. Deafness,

unfortunately, is usually permanent. Hemiplegia, when due to oedema of the brain, is transitory, but when due to encephalitis or to a vascular lesion is likely to be permanent. Recovery from meningococcal arthritis and orchitis is usually complete.

Prophylaxis.

Since meningococcal meningitis is spread chiefly by droplet infection from carriers, hygienic measures should be taken to ensure adequate ventilation and to avoid overcrowding in institutions and communities exposed to infection. Beds in dormitories should be placed not less than 3 feet apart. The detection of carriers by swabbing the nasopharynx is impracticable on a large scale but may be of value in communities in which infection has occurred. A carrier should be isolated from children and young persons and should take plenty of exercise and fresh air. The nasopharynx may be sprayed with a 1·5 to 2 per cent. solution of zinc sulphate, or a 1 per cent. solution of chloramine T. Treated on these lines most carriers cease to harbour the meningococcus in two or three weeks, but chronic carriers who do so for from six to twelve months exceptionally occur, and the convalescent may remain a carrier for a considerable time

Prophylactic vaccination has been used. Its value is uncertain, though good results have been claimed in some epidemics. It may reasonably be employed in cases of susceptible persons entering an infected community. Doses of 500 and 1,000 millions should be given, separated by a week's interval, the organisms employed being a mixture of the types predominating in the infected community.

Treatment.

The patient must be kept completely at rest in bed and should receive a liquid diet. Young children may require nasal feeding. The abdomen should be carefully examined daily for evidence of distension of the bladder. Sedative drugs will usually be required, bromides and luminal being the most useful.

The two most important measures in treatment, however, are the withdrawal of cerebro spinal fluid by lumbar puncture and the administration of sulphanilamide with or without anti-meningococcal serum

Lumbar Puncture

Lumbar puncture possesses definite value apart from the intrathecal injection of serum. Withdrawal of cerebro-spinal fluid lowers the intracranial pressure and so affords relief for headache. It also permits the withdrawal of fluid containing organisms and pus and

its replacement by fresh fluid, thus relieving to some extent the irritation of the meninges Whether or not serum is injected, intrathecal lumbar puncture should be carried out at least once a day and if necessary more frequently at first, until recovery occurs. For the method of performing lumbar puncture, see p. 114. If the operator is experienced and has skilled assistants it will rarely be necessary for a general anaesthetic to be administered, and this should be avoided if possible. Occasionally, however, the restlessness of the patient or an extreme degree of opisthotonos necessitates a general anaesthetic. For this purpose nitrous oxide and oxygen are to be preferred. Continuous drainage of the subarachnoid space by means of a lumbar puncture needle has been advocated, but presents practical difficulties in the nursing of the patient.

Sulphanilamide.

It is not yet possible to say whether sulphanilamide will entirely replace serotherapy. Though good results have been claimed for the drug alone, at present it is wise to give both methods of treatment. Sulphanilamide or sulphapyridine is given orally in doses of 1 gramme per stone of body weight daily, and in infants twice or three times this amount. This dose is reduced in three days and discontinued after nine days. Alternatively an initial dose of 1·5-2·5 gm. of sulphapyridine may be given intramuscularly in a suspension of 0·5 gm. to 5 c.c. of saline, a second smaller dose being given if necessary.

Serotherapy.

The introduction of sulphanilamide has reduced serotherapy to an accessory method of treatment and instead of being given intrathecally unconcentrated polyvalent serum is given intravenously or in the case of an infant intraperitoneally in a dose of 120 c.c. to an adult and 90 c.c. to a child on the first day, a smaller dose being given on the second day.

With this treatment the cerebro-spinal fluid usually rapidly clears and the temperature falls; and *lumbar puncture is not necessary* after three or four days.

Complications of Serum Treatment.

Anaphylactic collapse following the injection of serum is fortunately *rare and is likely to occur only in individuals who have received horse serum more than ten days previously.* The possibility of anaphylaxis may therefore arise when a patient has previously been treated with serum for some other complaint, for example diphtheria or tetanus, or when serum treatment has to be repeated for a relapse of meningococcal meningitis more than ten days after

the last dose. To ascertain whether an individual is sensitive to horse serum 0·25 c.c. may be given intradermally. In a sensitive person an urticarial wheal develops at the site of infection, usually within half an hour. Such a person can be desensitized by means of a preliminary injection of 1 c.c. of serum subcutaneously. A general anaesthetic, which abolishes the risk of anaphylaxis, should be used when serum is employed in the treatment of a relapse. 'Serum disease', which is characterized by slight fever, urticaria, and pains in the joints, is a common sequel of the administration of serum and usually occurs after eight or ten days. In cases of meningococcal meningitis a meningeal reaction characterized by an increase in headache and in signs of meningeal irritation may also occur. This is distinguished from a relapse by the absence of meningococci and the presence of sugar in the cerebro-spinal fluid.

Vaccine Treatment

A vaccine may be of value in the treatment of cases in which convalescence is slow. It should be prepared from the organism with which the patient is infected and should be given subcutaneously, beginning with a dose of 250 millions.

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TUBERCULOUS MENINGITIS

Aetiology.

Tuberculous meningitis has hitherto usually been regarded as part of a miliary dissemination of tubercle bacilli by the blood-stream. Rich and McCordock (1933) and MacGregor and Green (1937), however, believe that in most if not in all cases the infection spreads to the meninges from a caseous focus in the brain in contact with either the subarachnoid space or the ventricles The cerebral focus is infected via the blood stream from a focus which in children is often in the mediastinal or mesenteric lymph glands, but may be situated in the bones, joints, lungs, or genito-urinary tract   Tuber-culous meningitis may follow an operation upon an infected bone or joint and is not uncommonly the sequel of one of the specific fevers, especially measles.   There is sometimes a history of a fall or other injury. Tuberculous meningitis most frequently occurs in children between the ages of 2 and 5   It is rare during the first year, but may occur at any age. In young children there is usually no history of previous tuberculous infection in the patient, though inquiry may reveal the presence of tuberculosis in an adult member of the household. In adults tuberculous meningitis is usually the terminal event of an illness due to a focal infection with tuberculosis in the lungs or elsewhere.

In about one-quarter of all cases the infection is with the bovine bacillus, in the remainder with the human bacillus (MacGregor and Green 1937).

Pathology.

Macroscopically the brain is usually pale and the convolutions are somewhat flattened. A yellowish gelatinous exudate is found matting together the leptomeninges at the base and extending along the Sylvian fissures. Miliary tubercles are visible on the leptomeninges, being most conspicuous along the vessels, especially the middle cerebral artery and its branches. Microscopically the tubercles consist of collections of round cells, chiefly mononuclear, often with central caseation. Giant cells are rare. The substance of the nervous system shows little inflammatory reaction but marked toxic de-generation of nerve-cells.

Older caseous tuberculous foci can usually be found in the brain.

Symptoms.

The onset of symptoms is insidious, and there is almost always a prodromal phase of vague ill health. In children lassitude, anorexia, loss of weight, and change of disposition are present. In adults mental changes may be conspicuous and symptoms of a confusional psychosis may precede those of meningitis. The prodromal phase usually lasts two or three weeks and is followed by the development of symptoms of meningeal irritation. The pulse, which was previously rapid, becomes slow and irregular. Fever, if previously absent, usually now appears but is rarely high. The temperature, which is often markedly irregular, does not usually rise much above 102° F. Headache and vomiting make their appearance and convulsions may occur The patient becomes drowsy and at times delirious, but the occurrence of lucid intervals, even up to a late stage of the illness, is a characteristic feature. Signs of meningeal irritation are usually slighter than in pyogenic meningitis. There is usually slight cervical rigidity, but this may be absent and actual head retraction is rare. Kernig's sign is usually present. The patient frequently lies in a flexed attitude, resenting interference, and in the early stages often exhibits photophobia. Children sometimes utter what has been called a 'meningeal cry', a high-pitched scream.

Papilloedema is inconstant and when present usually develops only in the late stages of the illness. Choroidal tubercles may be visible ophthalmoscopically as rather ill-defined rounded or oval yellowish bodies about half the size of the disk, but this is exceptional The pupils are usually contracted at first, but later become dilated and fixed. Moderate ptosis is common. Paralysis of any of the oculomotor nerves may occur, leading to strabismus and diplopia. There is frequently facial weakness on one or both sides, and dysphagia develops in the later stages. Voluntary power in the limbs is at first little impaired, though a coarse tremor is usually present on voluntary movement. Hemiplegia occurs in a minority of cases. In the late stages the limbs become paralysed 'and general extensor rigidity is common. The tendon reflexes are not infrequently diminished or lost in the lower limbs in the early stages, but become exaggerated when rigidity develops. The plantar reflexes, at first flexor, usually later become extensor. Retention of urine in the early stages later gives place to incontinence. Constipation is the rule at first, later faecal incontinence occurs. The tâche cérébrale is common. The abdomen is retracted. Focal signs of tuberculous infection may be found, but signs of general miliary dissemination elsewhere than in the meninges are usually lacking. Pirquet's test, if positive, is of diagnostic value, but a negative result is of no significance.

The illness terminates fatally, usually about three weeks after the first appearance of meningeal symptoms, though its duration may be as short as a week or very rarely as long as four, or even five, weeks. Three stages of the disorder can often be recognized, each lasting approximately a week. During the first week the pulse is slow, during the second it becomes more rapid but shows fluctuations parallel with the temperature During the third week vagal paralysis develops and the pulse-rate increases to from 140 to 160 and the temperature sometimes rises to a terminal hyperpyrexia. By the end of the illness the comatose patient is much wasted and death usually occurs from medullary paralysis.

The Cerebro-spinal Fluid

The cerebro-spinal fluid is under increased pressure It is clear, but a fine 'cobweb' clot frequently forms on standing There is an increase in the number of cells, usually to the number of about 100 per c mm. These may be all mononuclear or a mixture of mononuclear and polymorphonuclear, the former predominating There is a moderate increase in the protein, up to about 0 1 per cent. The chloride content of the fluid is much reduced, on an average to 510 mg per 100 c.c , In Ingham's (1937) series of 84 cases only two had a chloride content above 550 mg. There is a diminution in the glucose content of the fluid and Lange's colloidal gold curve is of the meningitic type The frequency with which tubercle bacilli are found in the fluid varies in the hands of different workers. Some report that they are almost invariably demonstrable Others find them less often Consequently, though their presence clinches the diagnosis, their absence is of less significance. The inoculation of a guinea-pig is of little diagnostic value, since the patient, if suffering from tuberculous meningitis, is likely to be dead before the animal shows signs of infection.

Diagnosis.

Prognosis.

The disease is almost always, if not always, fatal in from one to four weeks after the onset of meningeal symptoms. Recovery has occasionally been reported after tubercle bacilli have been demonstrated in the cerebro-spinal fluid, but it is probable that these were cases of localized tuberculous meningitis around a caseous focus.

Treatment.

Treatment is symptomatic, lumbar puncture being used for the relief of headache, and sedatives, including morphine, being given in adequate doses. Bokay advocates deep X-ray irradiation of the head.

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MENINGITIS DUE TO TORULA

Infection of the central nervous system with the yeast, torula histolytica, or cryptococcus meningitidis, though rare, deserves mention on account of its liability to be confused with tuberculous meningitis or with intracranial tumour or abscess. The organism lacks mycelia, possesses a capsule, and forms spores. The characteristic lesion of the nervous system is a granulomatous meningitis, usually basal. Discrete granulomas are occasionally found. The meninges show diffuse or circumscribed granulomas with endothelial hyperplasia, fibrosis, moderate round-cell infiltration, and giant cells. Yeast-like organisms are usually numerous.

Of other organs in the body the lungs are most frequently involved, but the infection is occasionally generalized. The portal of entry is probably the respiratory tract.

The disease usually begins insidiously with symptoms of meningeal irritation, such as headache and rigidity of the neck. Papilloedema, sometimes going on to blindness, may occur, and there may be focal symptoms, such as aphasia or hemiplegia. The cerebro-spinal fluid usually shows an excess of lymphocytes and the diagnosis rests on the demonstration in it of the organism, which can usually be cultivated. Fever is usually slight or absent. The course of the disorder is usually progressive, though slight remissions are sometimes observed. The termination is progressive stupor, coma, and respiratory failure.

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SPINAL MENINGITIS

SPINAL PACHYMENINGITIS

See sections on Syphilis and Compression of the Spinal Cord
(pp. 395–6, 624).

SPINAL LEPTOMENINGITIS

Aetiology.

Infection of the spinal leptomeninges almost invariably occurs by
extension when the cranial leptomeninges become infected and also
as part of diffuse cerebro-spinal leptomeningitis when infection
reaches the meninges from the blood-stream The term 'spinal
leptomeningitis', however, is usually reserved for cases in which
meningitis begins within the spinal canal. Spinal meningitis thus
defined may occur as a result of direct infection of the spinal men-
inges through a penetrating wound Very rarely the infection is
introduced by lumbar puncture, or spreads down a pilonidal sinus
Otherwise it is usually due to the extension to the meninges of a
pyogenic infection in the neighbourhood of the vertebral column,
especially osteomyelitis, though occasionally no source of infection
can be found. Any pyogenic organism may be responsible There
is also a non-pyogenic form of spinal meningitis of unknown aetio-
logy characterized by an arachnoiditis of the roots of the cauda
equina.

Symptoms.

The onset of symptoms is usually subacute, the patient complain-
ing of severe pain in the lower limbs and lower part of the trunk,
especially in the spine. Moderate fever is present. The lower limbs
are maintained in a flexed attitude, are usually very tender, and an
attempt to extend them passively causes severe pain The reflexes
in the lower limbs are likely to be lost, but voluntary power is usually
preserved at first though much hampered by pain and tenderness.
Sensory changes are inconstant Retention of urine usually occurs
early and constipation is the rule. The cranial nerves and upper
limbs show no abnormality at first, though upward extension of the
infection may later lead to the picture of a generalized cerebro-spinal
meningitis when the organism is a pyogenic one. On lumbar punc-
ture the cerebro-spinal fluid contains pus, which may be so thick as
to be withdrawn only with difficulty. The infecting organism may
be demonstrable in films or on culture. In arachnoiditis of the
cauda equina the cerebro-spinal fluid is clear but contains an excess
of protein and lymphocytes

Diagnosis.

The condition may simulate acute anterior poliomyelitis or transverse myelitis, but when the organism is pyogenic the diagnosis is readily settled by the demonstration of pus in the cerebro-spinal fluid in the absence of signs of infection of the cerebral meninges. Otherwise the clinical picture is that of a subacute lesion of the cauda equina with a pleocytosis in the cerebro-spinal fluid.

Prognosis.

Pyogenic spinal meningitis is usually fatal, either as a result of extension of the infection to the cerebral meninges or the development of myelitis through infection of the substance of the cord, leading to flaccid paraplegia, but I have known recovery follow treatment with sulphanilamide.

Treatment.

The source of the infection should be sought and should receive appropriate treatment. Drainage by lumbar puncture is likely to be difficult owing to the thickness of the pus. The rational treatment of the condition would seem to be drainage of the lumbar sac by laminectomy combined with lavage of the spinal subarachnoid space with Ringer's solution introduced by cisternal puncture. Sulphanilamide should be given as for cerebro-spinal meningitis (see pp 353–4).

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SUPPURATIVE ENCEPHALITIS: INTRACRANIAL ABSCESS

Pathology.

INTRACRANIAL abscess may be (1) extradural, (2) subdural, (3) subarachnoid, or (4) intracerebral (1) Extradural abscess is secondary to osteitis of one of the cranial bones. The infection passes through the bone, but its further advance being arrested by the dura, the accumulating pus strips the dura from the bone. (2) In subdural abscess the infection has penetrated the dura and the pus lies between this membrane and the brain surface (3) Subarachnoid abscess is a rare form of subdural abscess in which the pus is limited to the subarachnoid space in which it spreads along the surface of the brain. (4) Intracerebral abscess may follow the spread of infection from the surface of the brain, or may be haematogenous. In the former case it usually, but not necessarily, possesses a track communicating with the surface. Intracerebral abscesses are usually single, but may be multiple, and, when multiple, sometimes communicate with each other The developing intracerebral abscess passes through three stages. The first stage is an acute encephalitis without visible pus formation. In the second stage pus makes its appearance, but the abscess is not well defined from surrounding tissue In the third stage a definite wall is formed, and the abscess is localized The localization of the abscess depends upon various factors, of which no doubt the resistance of the patient to the organism is one of the most important. In some cases it does not occur, and the condition remains in the stage of a spreading encephalitis.

Abscesses of otitic origin are usually situated in the middle or posterior part of the temporal lobe or in the cerebellum, the former situation being about twice as common as the latter. Much more rarely such abscesses occur in the pons, frontal, or parietal lobes. In otitic cases the brain may become infected as a result of either (1) purulent thrombosis of the lateral sinus or (2) osteomyelitis of the tympanic wall, or (3) by spread along the adventitial spaces of perforating blood-vessels (Evans, 1931) The anterior part of the frontal lobe is the seat of abscess following frontal sinusitis. Haematogenous abscesses may occur in any situation, but are nearly always above the tentorium. The left hemisphere is more often affected than the right, and in most cases the abscess lies in the area supplied by the middle cerebral artery.

Microscopically an intracerebral abscess consists of an inner layer of pus cells, outside which is a layer of granulation tissue

containing new blood-vessels and hyperplastic fibrous tissue. Outside this is a layer of glial reaction, mainly cellular in the early stages, mainly fibrous later. Fat granule cells, plasma cells, and polymorphonuclear leucocytes are plentiful, especially in the middle layer. Inflammatory reactions are present in the overlying meninges, and in extradural and subdural abscess granulation tissue is present on the surface of the dura.

Aetiology.

The causes of intracranial abscess in approximate order of frequency are: (1) infection of the middle ear, mastoid, and nasal sinuses, (2) pyaemic states, (3) metastasis from intrathoracic suppuration, and (4) head injury. In Evans's (1931) series of 194 cases of brain abscess the numbers for these groups were 121, 24, 22, 8, and other or unknown causes 19.

(1) Infection of the middle ear and mastoid is nine times as common a cause of cerebral abscess as infection of the nasal sinuses of which the frontal sinus is most often involved, and the sphenoidal sinus next.

(2) Intracranial abscess may be the outcome of pyaemia. In progressive endocarditis the infecting organism is usually of low virulence, and embolism leads to softening of the vessel wall and aneurysm formation more often than to abscess. The latter, however, may occur either in this or in more acute states of pyaemia, such as constitute the terminal event in acute osteomyelitis.

(3) When intracranial abscess is secondary to localized infection elsewhere, the thorax is usually the source, and most cases are complications of bronchiectasis, chronic empyema, or pulmonary abscess. Rarely the primary abscess is elsewhere, for example in the liver or a bone.

(4) Fracture of the skull is liable to cause abscess when the injury leads to free communication between the surface of the body and the brain, especially when fragments of bone, clothing, or a missile penetrate the latter.

Any of the common pyogenic organisms may be responsible for intracranial abscess, the commonest being *Streptococcus*, *Pneumococcus*, and *Staphylococcus aureus*. Friedländer's bacillus and organisms of the *Bacillus coli* group are also found. The causal agent may be a streptothrix, as in actinomycotic abscess, and amoebic abscess of the brain is known to occur.

Symptoms.

Mode of Onset.

The history of the development of the symptoms of an intracranial abscess may be of greater diagnostic importance than the physical

signs, which are often slight at the stage at which treatment is most likely to be effective.

When abscess follows fracture of the skull it usually develops soon after the injury, though when a missile penetrates the brain there may be a latent interval. These cases, however, offer little difficulty. The history is particularly important when abscess is secondary to otitis media or mastoiditis. In some such cases the onset is acute or subacute. Following an exacerbation of a pre-existing otitis media, or a temporary suppression of aural discharge, or the operation of mastoidectomy, the patient rapidly develops headache, vomiting, delirium, and other symptoms to be described. In other cases there is a 'latent interval' which may last months before the *signs* of abscess appear. The existence of *symptoms* during this period may suggest that all is not well. There may be attacks of headache, loss of appetite and weight, constipation, occasional unexplained pyrexia, and a change in temperament leading to depression and irritability.

Abscess of haematogenous origin may develop slowly and insidiously, in which case, unless the primary infective focus is discovered, it may be clinically indistinguishable from an intracranial tumour. It is not uncommon, however, to obtain a history of an acute disturbance of health corresponding to the lodgement of the infected embolus in the brain. This is the rule when the embolus lodges in a large and important vessel, such as the middle cerebral or one of its branches, and the embolic symptoms then tend to be permanent and to merge into those of the abscess. Even in other cases, however, there is often a history of sudden headache with perhaps some impairment of consciousness, and weakness of a limb, followed by a remission of these symptoms for weeks or months before those of the abscess develop.

The symptoms of intracranial abscess may be conveniently divided into (1) general symptoms of infection, (2) symptoms of increased intracranial pressure, (3) focal symptoms, and (4) changes in the cerebro-spinal fluid.

1. General Symptoms

The severity of the general symptoms is usually proportionate to the acuteness of the abscess, and is therefore most marked in the cases best described as acute suppurative encephalitis. In the acute cases an irregular pyrexia is the rule; in chronic cases the temperature is often subnormal. In both there may be a polymorphonuclear leucocytosis in the blood.

2. Symptoms of Increased Intracranial Pressure

The incidence of symptoms of increased intracranial pressure differs somewhat in abscess from that found in intracranial tumour.

Headache is usually present. In chronic abscess it is paroxysmal, is increased by stooping and exertion, and presents the other features of headache due to increased intracranial pressure. In more acute cases headache may be persistent and very severe. Papilloedema is a late sign and is often absent or slight. When present it is usually more marked upon the side of the lesion. Bradycardia is commoner in abscess than in tumour, but is not constant, and when it occurs usually indicates a rapid increase in the severity of the condition. In severe cases delirium, somnolence, stupor, and coma develop. Exceptionally the signs of increased intracranial pressure are slight or lacking, even when a large abscess is present.

3. FOCAL SYMPTOMS

(i) *Extradural Abscess.*

This is difficult to diagnose because, unless the abscess is very large, focal symptoms are absent, except for headache radiating from the ear and mastoid process towards the vertex. This is only of significance if the ear and mastoid are receiving adequate drainage, and hence can be excluded as the cause of the headache. Tenderness of the skull to pressure or percussion in front of or above the ear or behind the mastoid may also be present.

(ii) *Subdural and Intracerebral Abscess.*

1. *Temporo-sphenoidal Abscess.* Whether pus lies between the dura and the brain or intracerebrally usually cannot be determined before operation. An abscess in this position, if situated on the left side in a right-handed individual, may cause aphasia, usually of the nominal type, that is, a difficulty in naming objects. Investigation of this symptom requires care, and a patient who can name familiar objects accurately often shows hesitation, or misnames less familiar articles. Abscess on either side may produce a defect of the visual fields, an especially valuable localizing sign when present. It usually consists of a homonymous upper quadrantic defect on the opposite side due to involvement of the lower fibres of the optic radiation. Damage to the pyramidal tract is usually slight, and weakness is most marked in the face and tongue. The opposite plantar reflex may be extensor. Oculomotor paralyses may result from pressure upon the third or sixth cranial nerve.

2. *Cerebellar Abscess.* Headache in cerebellar abscess is often predominantly suboccipital. It may radiate down the neck and be associated with some cervical rigidity. The head may be flexed to the side of the lesion or retracted. Signs of cerebellar deficiency vary in severity and may be slight. The most important are—nystagmus, most marked on conjugate deviation to the side of the lesion, the

slow phase being centripetal; hypotonia, and inco-ordination in the limbs on the affected side, with an inability to carry out rapid alternating movements as well with the upper limb on the affected side as on the normal side. Pressure upon the brain-stem may occur, leading to compression of cranial nerves, especially the sixth and seventh, on the side of the abscess, and slight signs of pyramidal defect on the opposite side. Pass-pointing outwards with the affected hand and a tendency to deviate or fall to the side of the lesion when walking are additional signs which may be present.

3. *Frontal Abscess.* Headache, drowsiness, apathy, and impairment of memory and attention are usually conspicuous, but focal signs are often lacking. A large abscess or much oedema may cause aphasia or hemiparesis. Unilateral anosmia and slight exophthalmos may be present

4. *Abscesses in other Situations.* These require no special description, the focal symptoms depending upon the position of the abscess, and usually resembling those of tumour in the same situation

(iii) *Subarachnoid Abscess.*

This rather rare condition may be suspected when the signs point to abscess of otitic origin, though neither of the clinical pictures just described is present. Convulsions may occur with a superficial abscess of the cerebral hemisphere When the signs have pointed to involvement of the cerebellum but no abscess can be found in the cerebellum itself, search should be made for a superficial abscess in the cerebello-pontine angle.

4. The Cerebro-spinal Fluid

Examination of the cerebro-spinal fluid is often of great diagnostic value. As long as the abscess remains localized, the fluid is clear. Its pressure may be increased. There is usually an excess of cells, though not often more than 100 per c.mm., the majority of which are lymphocytes, the remainder being polymorphonuclear. the protein is somewhat raised There is no diminution in the chloride or sugar content, and organisms are absent The supervention of generalized meningitis upon intracranial abscess leads to a change in the cerebro-spinal fluid. The cells increase, and polymorphonuclears predominate, while the chloride content diminishes, and the fluid no longer yields reducing substances Organisms may be present.

Other Methods of Investigation.

Ventriculography may occasionally be necessary for localization but should only be performed immediately before operation. Exploratory puncture may be helpful in localization, and radiography

may be carried out after injection of an opaque substance such as perabrodil or thorotrast into the cavity.

Diagnosis.

Intracranial abscess is rarely encountered without an evident source of infection. It is then usually exposed at an operation for a supposed intracranial tumour. The diagnosis of such cases from tumour is difficult and often impossible. Pyrexia, leucocytosis in the blood, and an excess of cells in the cerebro-spinal fluid, however, may suggest the correct diagnosis. When the causal infective focus is obvious it is necessary to distinguish abscess from other pyogenic intracranial complications. Generalized meningitis, which may co-exist with abscess, is distinguished by the prominence of signs of meningeal irritation, cervical rigidity, in severe cases head retraction, Kernig's sign, and the changes in the cerebro-spinal fluid already described. Lateral sinus thrombosis causes little cerebral disturbance, though the resulting congestion may cause slight papilloedema, more marked on the affected side, and slight signs of pyramidal defect on the opposite side. The signs of pyaemia are usually conspicuous with swinging temperature and rigors. A valuable sign may be demonstrated by Queckenstedt's test. The rise of cerebro-spinal fluid pressure may be slight or absent when the jugular vein on the affected side is compressed alone, because the blocked lateral sinus prevents communication of the raised jugular pressure to the cranial cavity. Acute labyrinthitis may be confused with cerebellar abscess, with which it may coexist. In the former vertigo is more, and headache less, intense than in the latter. In the nystagmus due to labyrinthitis the slow phase is always in the same direction, to which-ever side the patient directs his gaze. In cerebellar abscess the slow phase is always away from the point of fixation. Evident hypotonia is in favour of a cerebellar lesion. Papilloedema and changes in the cerebro-spinal fluid indicate that the infection has passed beyond the internal ear.

Prognosis.

Very rarely an intracranial abscess becomes quiescent and is found accidentally at post-mortem, surrounded by a thick layer of gliosis. Recovery by spontaneous drainage may also occur. These occur-rences, however, are too exceptional to have any bearing upon prognosis, which may be regarded as uniformly fatal in the absence of surgical interference. Spreading encephalitis, rupture of the abscess into the ventricular system, meningitis, and sinus thrombosis are the usual terminations. Even after surgical drainage these com-plications may occur, and the mortality rate is high.

Treatment.

An acute abscess is ill defined and if possible operation should be delayed for three or four weeks to allow the abscess to become walled off. Increasing coma or the presence of organisms in the cerebro-spinal fluid is an indication for operation in the acute stage. Chronic abscess should be operated on without delay. Operative methods are discussed by Cairns and Donald, (1934), and Symonds and Cairns (1936). Drugs of the sulphanilamide group may be given as for meningitis (see p. 353).

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CHAPTER VIII

NERVOUS COMPLICATIONS OF MISCELLANEOUS INFECTIONS

1 ACUTE TOXIC ENCEPHALOPATHY

Synonyms· Acute toxic encephalitis, acute serous encephalitis.

Definition: An acute cerebral disturbance occurring chiefly in children, not uncommonly in small epidemics and characterized pathologically by toxic changes in the nervous system, and clinically by delirium or coma and convulsions, cerebral palsies, and symptoms of meningeal irritation.

Pathology.

The changes in the nervous system distinguish this disorder both from the forms of encephalitis which are caused by the invasion of the nervous system by a virus, and from those in which demyelination is present. Pathologically there is an acute degeneration of the ganglion cells of the brain with hyperaemia and conspicuous perivascular and pericellular oedema, and focal collections of glial cells and round cells. Ring haemorrhages have been described, and 'acute haemorrhagic encephalitis', in which multiple punctate haemorrhages with a perivascular distribution are conspicuous in the nervous system, is probably an intense variety of this disorder.

Aetiology.

The pathological changes are interpreted as the effect of a toxaemia which varies in the severity of its incidence upon nerve cells and the blood-vessels, so producing varying degrees of neural degeneration, oedema, and haemorrhage. In some cases the source of the toxaemia is a focal or generalized pyogenic infection. In others it is unknown and this applies to the small epidemics of the disorder which sometimes attack young children during the summer months. It is not very common in infancy, most cases occurring between the ages of two and ten years.

Symptoms.

The onset of the illness is usually acute and may be fulminating. It is sometimes preceded by sore throat or gastro-intestinal disturbance. Severe headache, vomiting, and convulsions are common and the latter may be predominantly unilateral. The child when conscious is usually delirious, but may pass later into coma. There is usually high fever. Meningeal symptoms are often conspicuous.

Involvement of the cerebral hemispheres may lead to aphasia, monoplegia, hemiplegia, or double hemiplegia. Optic neuritis may occur; *pupillary abnormalities are inconstant. Trismus is sometimes seen* and facial paresis is frequently present. The tendon reflexes are not uncommonly diminished or lost, but may be exaggerated, and the plantar reflexes extensor on one or both sides. *Retention and incontinence of urine are common when consciousness is clouded* or lost. The symptoms may be predominantly meningeal, cerebral, or spinal. The cerebro-spinal fluid is usually normal in composition though under increased pressure. Exceptionally there may be a pleocytosis or a rise of protein content. Rarely, chiefly in those cases characterized pathologically by acute haemorrhagic encephalitis, haematuria or albuminuria may occur and a purpuric rash has been described.

Diagnosis.

The fact that the cerebro-spinal fluid is usually normal in composition and the early involvement of the substance of the nervous system distinguishes acute toxic encephalopathy from the various forms of meningitis. The diagnosis from poliomyelitis is based upon the absence of a considerable pleocytosis, the presence in many cases of extensor plantar responses, and the absence of muscular wasting. The infrequency of ocular palsies, especially of pupillary abnormalities, and the frequent occurrence of symptoms of massive lesions of the cerebral hemispheres distinguishes the disorder from encephalitis lethargica.

Prognosis.

The prognosis varies in different groups of reported cases. In some small epidemics almost all the affected individuals have died. In others almost all have recovered. In fatal cases death usually occurs within two or three days of the onset, coma having supervened within a few hours. In those who survive the dangers are the persistence of mental defect, aphasia, hemiplegia, or epilepsy. Sometimes the patient recovers from unconsciousness and hemiparesis clears up in a few days. In other cases improvement is slower but recovery is often surprisingly complete.

Treatment.

Treatment is symptomatic. Lumbar puncture with free-drainage of the cerebro-spinal fluid is often helpful. Phenobarbital or other sedatives *may be required to control the convulsions*. Coma may be treated by 1 or 2 oz. of 25 per cent. solution of magnesium sulphate per rectum.

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2. SCARLET FEVER

Nervous complications of scarlet fever are rare. Although focal vascular lesions have been reported, the pathological changes in most cases which have been investigated recently have consisted of acute haemorrhagic encephalitis. Meningism is not uncommon, symptoms of meningeal irritation coexisting with a normal cerebro-spinal fluid. True meningitis occurs less frequently and is usually secondary to otitis or other complications produced by pyogenic organisms. In a few cases the *Streptococcus scarlatinae* has been isolated from the fluid. Hydrocephalus has been reported in a few instances as a sequel of meningitis complicating scarlet fever. Cerebral abscess may occur apart from otitis, and I have seen an example of this. Hemiplegia, however, is the commonest complication resulting from involvement of the nervous system. Rolleston has collected 66 cases from the literature. It is usually embolic in origin but may follow cerebral thrombosis or haemorrhage or acute encephalitis. Hypertensive encephalopathy may be responsible for cerebral symptoms. A few cases of localized and multiple neuritis have been reported. Optic neuritis is rare. Chorea is a not uncommon sequel of scarlet fever. Encephalitis and meningitis due to complicating pyogenic organisms are usually fatal. Recovery has occurred in cases of meningitis due to the *Streptococcus scarlatinae*. Hemiplegia of vascular origin is usually permanent, but symptoms due to hypertensive encephalopathy disappear if the patient recovers.

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3. WHOOPING-COUGH

The pathogenesis of nervous symptoms in whooping-cough is varied. Some are due to focal vascular lesions, especially haemorrhages. Jarke has described multiple patches of softening of the cerebral hemispheres and Askin and Zimmerman have reported a case of encephalitis with focal collections of inflammatory cells. Convulsions are not uncommon in whooping-cough, especially in young children. Though they may sometimes be due to transitory metabolic or other functional disturbances, in severe cases the pathological changes of encephalitis have been found. Focal symptoms, which include aphasia, unilateral or bilateral hemiplegia, blindness, and deafness, are probably the result of focal vascular lesions or softening. Peripheral nerve palsies are rare and usually late complications. Patients who have severe and frequent convulsions usually die. Of the group with focal lesions, according to Londe, one-fifth die, two-fifths are incapacitated by residual symptoms, and two-fifths recover.

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4. TYPHOID FEVER

Mental symptoms are common, those most frequently encountered being acute toxic confusional states during the febrile period and post-typhoid insanities of many forms, the nature of which in individual cases probably depends upon the psychological constitution of the patient. Meningeal symptoms may be due to meningism, the cerebro-spinal fluid being normal. Much more rarely true meningitis occurs, due to infection with the *Bacillus typhosus*, the cerebrospinal fluid containing polymorphonuclear cells, together with the causal organism. Suppurative meningitis may also result from infection with other pyogenic organisms, with or without the *Bacillus typhosus* The substance of the nervous system is less often involved than the meninges, but focal symptoms, especially hemiplegia, with or without aphasia, may occur, and are probably usually vascular in origin, being most frequently due to cerebral thrombosis. Optic neuritis is rare. Cerebral abscess may occur either by extension from otitis media or by metastasis from a focus of pyogenic infection elsewhere. Such abscesses are usually due to a secondary invader, but may be caused by the *Bacillus typhosus*. Occasionally spinal symptoms predominate, yielding a picture of transverse myelitis or of ascending paralysis of the Landry type. Neuritis is a rare sequel, polyneuritis involving the feet and causing tenderness of the toes being the commonest form.

Similar complications may occur in paratyphoid fever, but less frequently than in typhoid.

Meningitis occurring in typhoid fever is usually fatal, and cerebral abscess is a serious complication which usually terminates fatally. Focal vascular lesions do not threaten life to the same extent, but frequently cause permanent disability, e g. hemiplegia.

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5. TYPHUS FEVER

Nervous complications are not uncommon in typhus fever, and there is abundant evidence that they are usually due to infection

of the nervous system by the causative organism. Histologically microscopical nodules in the walls of the very small blood-vessels—typhus nodules—have frequently been observed in the nervous system, where they consist of perivascular collections of glial, endothelial, and other mononuclear cells (Aschoff, Wolbach, Spielmeyer, and others) Thrombosis frequently occurs in the affected vessel. The *Rickettsia prowazeki*, which is believed to be the causal organism of typhus, has been seen in the endothelium of the cerebral vessels and sometimes in the typhus nodules.

Headache, delirium, and insomnia, which are common during the febrile stage of the illness, are probably toxic in origin and do not necessarily indicate invasion of the nervous system. Focal nervous symptoms indicative of the latter usually occur during the last few days of the febrile period or within a few days afterwards. Meningeal symptoms may occur, and any part of the nervous system may be involved. Cerebral symptoms may indicate multiple lesions, a disseminated encephalitis, but hemiplegia is the commonest symptom. An acute cerebellar ataxia occurs in a small proportion of cases, and multiple bulbar foci may occur, leading to dysphagia and dysarthria. Lesions are sometimes confined to the spinal cord, yielding the clinical picture of a myelitis. The cranial and peripheral nerves frequently suffer. Optic neuritis may occur. Facial paralysis is particularly common, and deafness is not rare In the peripheral nerves the symptoms may be those of a focal interstitial neuritis, associated with pain and tenderness, or of a polyneuritis

Changes are frequently present in the cerebro-spinal fluid, which is sometimes xanthochromic and may exhibit a lymphocytosis. The albumin content of the fluid is usually little raised, but an excess of globulin, as indicated by a positive Noguchi reaction, is present in 50 per cent. of cases and may persist for from two to eight months after the acute stage (Danielopolu and De Vaux).

The occurrence of severe nervous symptoms naturally adds to the gravity of the prognosis. In patients who survive, cerebral symptoms are frequently permanent, and Grodski speaks of chronic encephalitis following typhus.

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6. MALARIA

Acute nervous symptoms in malaria occur chiefly in infections with the malignant tertian parasite and are due to sporulation of the parasite in the cerebral capillaries. Sections of nerve tissue exhibit macroscopically a smoky grey appearance with oedema, hyperaemia, and punctiform haemorrhages. Histologically the chief abnormality is more or less complete blocking of capillaries with parasitized red cells, leading to thrombosis, oedema, and petechial haemorrhages. The leptomeninges exhibit a perivascular infiltration with small, round cells. Malarial nodules (granulomas) have been observed. These consist of a central capillary filled with parasitized red cells and surrounded by a perivascular necrotic area, with glial proliferation (Thompson and Annecke).

Acute cerebral malaria is characterized by rapidly developing coma, with or without precedent convulsions. Symptoms of meningeal irritation may occur, especially in children. In such cases the prognosis is always very grave. Focal manifestations include hemiplegia, aphasia, and cerebellar ataxia, which are usually transitory. Paraplegia has been described. Optic neuritis and retinal haemorrhages are not very uncommon, and complete external ophthalmoplegia may occur.

Chronic nervous symptoms in malaria are probably toxic in origin and are usually due to neuritis. Trigeminal neuralgia, facial paralysis, localized neuritis of single nerves of the upper and lower limbs, and polyneuritis may occur.

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7. INFLUENZA

Nervous symptoms are frequently attributed to influenza, but the diagnosis is usually speculative and, except in cases occurring during epidemics, should always be received with caution. Pfeiffer's bacillus may cause meningitis, though this is rare. Acute haemorrhagic

encephalitis has been ascribed to influenza, and recently Greenfield has reported two cases of acute disseminated encephalo-myelitis characterized by perivascular demyelination which followed a febrile illness diagnosed as 'influenza'. Small epidemics of encephalitis and *polyneuritis have been observed to coincide with epidemics of influenza*. Proof, however, is lacking that these forms of encephalitis are actually due to influenza or even that they complicate this disorder, since a precedent febrile illness, when it occurs, may well be due to invasion by the organism which is responsible for the nervous symptoms. The occurrence of mental symptoms, especially depression and lassitude, and of localized interstitial neuritis after influenza is, however, well established.

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TREATMENT

The treatment of the nervous complications of the foregoing acute infections is primarily that of the infection itself, including the use of immune serum (e.g. in scarlet fever) or of convalescent serum, when this is available. Otherwise treatment is symptomatic and should be carried out on the lines laid down for other forms of encephalitis and meningitis.

SYPHILIS OF THE NERVOUS SYSTEM

Aetiology.

SYPHILIS is the most frequent disease of the nervous system and is the cause of one in every seven cases of organic nervous disease. Until the present century the full range of its manifestations could only be guessed. Headache and palsies were attributed to syphilis in the Middle Ages, but there was little exact knowledge of neurosyphilis before the nineteenth century. Boyle described general paralysis in 1822, and the first adequate account of tabes was given by Romberg in 1846, and amplified by Duchenne and Charcot. Argyll Robertson described the pupillary abnormalities which bear his name in 1869. Fournier, also in 1869, described congenital syphilis and introduced the conception of parasyphilis. The discovery of the causal organism in the *Treponema pallidum* or *Spirochaeta pallida* by Schaudinn and Hoffmann in 1903 and the elaboration of the Bordet-Wassermann reaction (1901-7) have rendered it possible to identify conditions as syphilitic, the relationship of which to syphilis was previously a matter of speculation. There are still, however, many unsolved problems in the aetiology and classification of neurosyphilis.

Although the earliest manifestation of acquired syphilitic infection is the primary chancre, it has been proved that spirochaetes may obtain access to the blood and be present in the spleen within ten days of infection and before the chancre appears. There is evidence, which will be described later, that in the secondary stage spirochaetes have reached the nervous system in a large proportion, probably in the majority of persons infected, though they may not then give rise to symptoms. The secondary stage is usually followed by a period of latency, but even within a year, frequently within two or three years, symptoms of the tertiary stage may develop.

On clinical grounds a distinction has long been drawn between two groups of tertiary manifestations of neurosyphilis, one of which has been known as meningo-vascular or cerebro-spinal syphilis, the other, which comprises tabes and general paralysis, being distinguished as parenchymatous syphilis, parasyphilis, or metasyphilis. In meningo-vascular or cerebro-spinal syphilis symptoms may occur within a few *years of infection, tend to be focal, and on the whole respond well* to treatment. Tabes and general paralysis, on the other hand, exhibit a longer latent interval, are characterized by diffuse or systematized pathological changes, and respond less satisfactorily to treatment. We are still ignorant of the true basis of this clinical distinction, and the names which have been applied to the two varieties of tertiary

neurosyphilis are therefore unsatisfactory. Neither a cerebro-spinal distribution nor involvement of the meninges and blood-vessels is peculiar to the more benign form, and destruction of the parenchyma of the nervous system is not limited to tabes and general paralysis. McIntosh and Fildes have with much cogency put forward the view that in cerebro-spinal or meningo-vascular syphilis the essential lesion is limited to the blood-vessels and the mesoblastic tissues and that the parenchyma of the nervous system suffers secondarily, while in tabes and general paralysis there is invasion of the nervous tissue itself by spirochaetes in addition to a mesoblastic reaction. This hypothesis justifies the use of meningo-vascular syphilis as a convenient, though not a strictly accurate, term for the more benign form of tertiary neurosyphilis and of parenchymatous neurosyphilis for tabes and general paralysis.

Neurosyphilis occurs in only a small proportion—about 10 per cent.—of persons infected with the *Spirochaeta pallida*. It has been supposed that certain strains of spirochaetes possess an affinity for the nervous system, while others do not. In favour of this view it has been stated that in some instances a number of individuals infected by the same person have all developed neurosyphilis, that the primary sore and secondary cutaneous manifestations may be slight or absent in persons who subsequently develop neurosyphilis and that in certain countries where syphilis is rife and other visceral manifestations are common, involvement of the nervous system is rare. Levaditi claims to have separated dermotropic and neurotropic forms of spirochaeto by means of experimental inoculation. These arguments have not been accepted as conclusive evidence for the existence of a neurotropic strain of spirochaetes. It appears, however, that individuals and races who develop a sharp primary and secondary reaction to the infection are less likely to develop neurosyphilis than those who react less severely. Recently modern intensive methods of treatment of syphilis have been blamed as a cause of the subsequent development of neurosyphilis, and it has been suggested that such treatment may diminish the patient's natural powers of resistance to the organism or may permit the development of resistant strains of spirochaetes in the nervous system. This theory, however, has not received general support, and in any case the early *and intensive treatment of infected persons, by diminishing their* infectivity, is certainly reducing the prevalence of neurosyphilis.

It has been suggested that the route by which the infection reaches the nervous system may influence the character of the tertiary nervous manifestations. In most cases the nervous system is probably infected through the blood-stream, though the cerebro-spinal fluid may play a secondary part in the dissemination. Orr and

Rows have claimed that the virus or its toxins may reach the nervous system by ascending the perineural lymphatics and that this route of invasion may be responsible for the development of general paralysis and tabes. A lymphogenous infection may possibly play a part in the causation of tabes, but it is difficult to interpret the pathological changes in general paralysis in this way.

Various factors have been regarded as predisposing to the development of neurosyphilis, especially alcoholism, other infections, mental strain, and inherited mental instability, but their importance in causation is difficult to assess.

SECONDARY NEUROSYPHILIS

Pathology.

Spirochaetes may reach the nervous system during the primary stage and before the development of the cutaneous exanthem. Nicolau found a lymphocytosis in the cerebro-spinal fluid in 9 per cent. of cases at this stage. In the secondary stage abnormalities have been found in the fluid in from 30 to 80 per cent. of cases in different series. Little is known of the pathology of this stage, as the condition is rarely fatal. In a small number of acute and fatal cases of secondary neurosyphilis the brain has been oedematous, but otherwise histological changes have been almost confined to the leptomeninges. The pia mater and arachnoid have been congested and have lost their translucency and have exhibited a diffuse cellular infiltration which has been most marked round the vessels, which have shown endarteritis.

Symptoms.

There may be no symptoms referable to the nervous system in spite of the presence of slight changes in the cerebro-spinal fluid, or the symptoms may be no more severe than the headache and pains in the back and limbs commonly associated with the secondary stage of syphilis. Exceptionally, symptoms of considerable severity may occur between the onset of the secondary stage and the end of the first year after infection. When the onset of these symptoms is insidious they are indistinguishable from the later manifestations of meningo-vascular syphilis described in the next section. Very rarely an acute and rapidly fatal meningo-encephalitis may occur during the first year after infection, characterized by generalized convulsions and quickly deepening coma. Polyneuritis has been described during the first year after infection.

The term 'neuro-relapse' has been applied to the subacute development of nervous symptoms within a few months of the secondary stage in a patient who has received inadequate treatment. The

symptoms of a neuro-relapse are commonly more severe than would be likely to occur in an untreated individual, and it appears that partial treatment, while failing to destroy many of the spirochaetes, may either reduce the patient's resistance or render him hypersensitive, so that further multiplication of the spirochaetes may be followed by a severe reaction. Convulsions, coma, severe headache, papilloedema, ocular palsies, aphasia, or hemiplegia may occur in such patients.

The Cerebro-spinal Fluid.

In patients in the secondary stage who show no symptoms of involvement of the nervous system the changes in the cerebro-spinal fluid are usually slight and are present in from one-third to one-half of all cases. They consist of a slight increase in the number of mononuclear cells or of the globulin or of both. The Wassermann reaction is negative in the fluid but may be positive or negative in the blood, according to whether the patient has received treatment. Patients suffering from nervous symptoms are likely to show more marked changes in the fluid, and these are usually proportional to the severity of the symptoms. When clinical evidence of meningitis is present, pressure of the fluid is usually raised and the cell content is increased and may be as high as 1,000 per c.mm. The cells are usually mononuclear, but in the most acute cases polymorphonuclear cells may also be present. Tests for globulin are positive and the Wassermann reaction is usually positive in the fluid, if from 0·5 to 1 c.cm. is used. It is usually positive in the blood, but may be negative if the patient has been treated.

For **Diagnosis, Prognosis,** and **Treatment,** see pp. 394–5, 399.

TERTIARY MENINGO-VASCULAR SYPHILIS

Cerebral Syphilis

Pathology.

The essential lesion in meningo-vascular syphilis is a vascular and perivascular inflammation (Fig. 42). The affected vessel exhibits a proliferation and inflammatory infiltration of its wall—endarteritis obliterans—and the perivascular space is infiltrated with lymphocytes, plasma cells, and usually with fibroblasts. The proliferation of the fibroblasts leads to fibrosis, while impairment of blood-supply through reduction of the lumen of the vessel, or actual thrombosis, together no doubt with the action of toxins produced by the organism, causes necrosis or caseation of neighbouring tissues. The result is a gumma, which is a granuloma originating in a patch of perivascular inflammation leading to necrosis, sur-

rounded by a zone of fibrotic reaction. Spirochaetes are scanty and difficult to demonstrate in all tertiary syphilitic lesions, but they have been found in the periphery of cerebral gummas. This characteristic reaction of the mesoblastic tissues to the spirochaete is the pathological basis of all forms of meningo-vascular syphilis. Clinical manifestations depend entirely upon the site of the process.
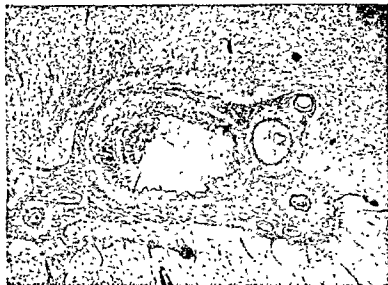
FIG 42 Meningo-vascular syphilis. Endarteritis and perivascular inflammation.

Cranial Pachymeningitis.

Syphilitic inflammation of the dura mater of the cranium is comparatively rare. It may be secondary to osteitis of the bones of the vault, or the dura may be involved apart from the bone. The underlying leptomeninges usually become adherent to the dura, the whole forming a dense membrane which may cover the greater part of one or both cerebral hemispheres and may be haemorrhagic.

Gummatous Leptomeningitis.

Gummatous leptomeningitis is a common manifestation of neurosyphilis. The basal meninges are frequently affected, but the process may be confined to those covering the convexity of the cerebral hemispheres. The arachnoid and pia mater form an adherent thickened membrane, which may contain a gummy exudate and small gummas.

Cerebral Endarteritis.

Although endarteritis occurs in all cerebral syphilitic lesions, it assumes especial importance when a main arterial trunk is the site of the process. Progressive occlusion of an artery usually leads finally to thrombosis and causes focal symptoms corresponding to the part of the brain supplied by the vessel.

Gumma.

Small cerebral gummas are common and they are usually multiple and take origin from the meninges. They are usually rounded, greyish in colour, surrounded by a pink vascular zone. They may be relatively soft from central necrosis, or tough, when fibrosis predominates. A cerebral gumma which is sufficiently large to give rise to increased intracranial pressure is very rare and is usually found as a subcortical mass in one cerebral hemisphere.

Symptoms.

Meningo-vascular syphilis may cause symptoms within a few months of infection or at any subsequent period in the patient's life. In most cases, however, symptoms develop within the first five years after infection. Symptoms are very varied on account of the multiplicity and different sites of the lesions. Frequently symptoms of both cerebral and spinal syphilis are present in the same patient.

Latent Meningo-vascular Syphilis.

It is important to recognize that abnormalities due to meningo-vascular syphilis may be found on routine examination of the nervous system in an individual who has never suffered from symptoms. Similarly they may have been present for years without causing symptoms in a patient who comes under observation complaining of a focal lesion of recent onset. The most important signs of latent neurosyphilis are inequality and irregularity of the pupils, with a sluggish reaction to light or actual Argyll Robertson pupils, inequality of the tendon reflexes, especially in the lower limbs, and unilateral or bilateral extensor plantar responses.

Cranial Pachymeningitis.

This rare condition may give rise to no symptoms apart from headache, but when the dura is adherent to the leptomeninges over the cortex there are likely to be symptoms of cortical irritation, such as focal convulsions and paresis of the limbs. (See also Subdural haematoma.)

Cerebral Leptomeningitis.

The symptoms of gummatous leptomeningitis may be relatively diffuse or sharply focal, for example, limited to one cranial nerve. When the lesions are diffuse the onset of symptoms is usually insidious. Headache is frequently severe, with nocturnal exacerbations, and may be associated with tenderness of the scalp. Papilloedema may occur. Mental changes are common. In mild cases these consist of impairment of memory and of intellectual capacity. The patient becomes inefficient at his work and if, as is not uncommon, he exhibits anxiety and nervousness, the condition may be mistaken for neurasthenia. In more severe cases there is marked apathy with gross mental deterioration amounting to dementia, or the mental state may resemble that of Korsakow's psychosis. Aphasia may be present and loss of sphincter control is common. The patient may finally pass into a state of semi-stupor. When the meninges over the convexity of the cerebral hemispheres are involved, convulsions may occur. These may be Jacksonian attacks without loss of consciousness, or generalized fits in which consciousness is lost. Paresis and inco-ordination of the limbs on one or both sides are common. Basal meningitis frequently involves the chiasmal region and may thus lead to optic atrophy with defects of the visual fields. Disturbance of the functions of the hypothalamus may cause obesity, diabetes insipidus, transient glycosuria, or narcolepsy. Hydrocephalus occasionally occurs. Reflex iridoplegia is almost constant and cranial nerve palsies are common, the nerves being involved in gummatous inflammation in their passage through the meninges. They may be affected singly or in association with adjacent nerves and usually unilaterally. The third nerve is most frequently affected, and painless third-nerve palsy as an isolated symptom is not infrequently the cause of the patient's coming for treatment. The paralysis of the intrinsic and extrinsic ocular muscles supplied by the nerve may be incomplete. Its onset is usually rapid. Next in frequency the sixth, seventh, and fifth cranial nerves are liable to be attacked. Thus facial paralysis clinically indistinguishable from Bell's palsy may be syphilitic in origin. When the fifth nerve suffers, sensory disturbances are more common than motor weakness. Neuralgic pain referred to the distribution of one or more of its branches may be associated with either hyperalgesia or analgesia and sometimes with ophthalmic herpes zoster or neuropathic keratitis. Syphilitic lesions of the eighth nerve may cause vertigo or deafness. The nerves arising from the medulla may be involved, the twelfth suffering more frequently than the tenth and eleventh, but any of the three may be affected either alone or in combination with the others.

Cerebral Endarteritis.

Any cerebral artery may be the site of syphilitic endarteritis. Before occlusion is complete there are frequently premonitory motor or sensory symptoms due to ischaemia of the region supplied by the vessel. Finally, thrombosis leads to symptoms of infarction which are described elsewhere; see p. 284. The middle cerebral artery or its branches and the posterior cerebral are most frequently the site of syphilitic thrombosis, but the anterior cerebral or the arteries of the brain-stem may be involved.

Hemiplegia is the commonest manifestation of cerebral thrombosis due to syphilis and may occur as a result of occlusion, either of the middle cerebral artery itself or of one of its basal branches supplying the internal capsule. Hemiplegia usually occurs within two or three years of infection. Its onset is rapid and associated with headache, but not with loss of consciousness. Syphilitic hemiplegia is rarely bilateral.

Parkinsonism is a very rare manifestation of cerebral syphilis, but has occasionally been described in association with symptoms of syphilitic inflammation of the midbrain.

Cerebral Gumma.

The symptoms of a cerebral gumma are those of an intracranial tumour situated usually subcortically in one cerebral hemisphere. The syphilitic origin of the tumour can only be inferred from the history of infection, the presence of signs of syphilis elsewhere, and a positive Wassermann reaction in the blood or cerebro-spinal fluid. Cerebral gumma is very rare, however, whereas both intracranial neoplasm and syphilitic infection are common and may be present in the same individual. A positive Wassermann reaction, therefore, must not be interpreted as indicating that a space-occupying lesion within the skull is necessarily, or even probably, a gumma.

The Cerebro-spinal Fluid.

In latent neurosyphilis the Wassermann reaction may be either positive or negative in the blood, but there is frequently no abnormality in the cerebro-spinal fluid. In cases of active meningo-vascular syphilis the Wassermann reaction is positive in the blood in 60 or 70 per cent. of cases. The pressure of the cerebro-spinal fluid may be either normal or increased. There is usually an excess of cells ranging between 20 and 100 per c mm., though the latter number may be exceeded. The cells are mononuclear. The protein content of the fluid is usually increased and lies between 0·05 and 0·15 per cent. An increase in the globulin is almost invariably present, and the Wassermann reaction is positive in from 90 to 100 per cent. of cases

when 1 c.c. of fluid is used. In cases of syphilitic cerebral thrombosis the Wassermann reaction may be positive in the blood and negative in the fluid. Lange's colloidal gold test yields either a 'paretic' curve, e.g. 5542210000, or a 'luetic' curve—1355421000. The colloidal benzoin test is likely to yield a positive reaction, that is, complete precipitation in the first five tubes.

Diagnosis.

Cerebral syphilis is so protean in its manifestations that its diagnosis covers a large field of clinical observation. Fortunately, serological tests come to the aid of clinical observation. It is rare that the Wassermann reaction is negative in the cerebro-spinal fluid in active cerebral syphilis, and still more rare to find the reaction negative in both the cerebro-spinal fluid and in the blood. Any suspicion of syphilis should, therefore, lead to the examination of both.

The mental changes associated with cerebral syphilis require to be distinguished from other mental disorders and in their milder forms from neurosis. A clue to their true nature is usually afforded by the presence of abnormalities in the nervous system, especially in the pupils and their reactions.

Subacute syphilitic meningitis must be differentiated from tuberculous meningitis. Both possess in common not only some clinical features, but also certain changes in the cerebro-spinal fluid, for example, lymphocytosis and an increase in the protein and globulin. In syphilis, however, the Wassermann reaction is almost always positive and the chloride content of the fluid is normal, whereas in tuberculous meningitis the Wassermann reaction is negative, the chloride content is considerably diminished, and tubercle bacilli may be found

When meningo-vascular syphilis is associated with papilloedema it may be confused with other conditions causing increased intracranial pressure, especially intracranial tumour. The symptoms in syphilis, however, rarely suggest a single focal lesion, and if such are present a tumour should not be too readily excluded, even if the Wassermann reaction is positive, since it is not very rare for a tumour to develop in a patient suffering from syphilis.

When either focal or generalized epileptiform attacks appear for the first time in adult life care must always be taken to exclude syphilis as a cause.

Cerebral thrombosis of syphilitic origin usually occurs at an earlier age than thrombosis due to atheroma, but otherwise it can be distinguished from the latter only when a history of infection or other signs of syphilis are present, or in their absence, by serological tests.

Meningo-vascular syphilis, since it frequently causes multiple

cerebral lesions, may be confused with encephalitis lethargica and with disseminated sclerosis. In encephalitis a history of the acute attack is often obtainable, though less frequently to-day than previously. The reaction of the pupils on convergence is more often impaired than that to light, whereas in cerebral syphilis the opposite is the case, and Parkinsonian symptoms of varying severity are frequently present. In disseminated sclerosis it is very rare for the pupillary reflexes to be affected, and nystagmus and inco-ordination of the limbs in the absence of sensory loss are rare in syphilis and common in disseminated sclerosis.

Prognosis.

The prognosis of cerebral syphilis is on the whole good, and excellent results are often obtained from energetic treatment. When severe mental symptoms have occurred, however, although there may be marked improvement, the patient is likely to be left with some impairment of intellectual efficiency and emotional stability. The results of vascular occlusion are permanent, and though some improvement may follow the disappearance of shock following the onset of the lesion, there is likely to be little further change for the better in hemiplegia, and the hemianopia resulting from posterior cerebral thrombosis persists unaltered Relapses are not uncommon, especially in patients who have abandoned treatment. They are less likely to occur in those who are thoroughly treated and kept under regular observation.

Treatment.

See p. 399.

Spinal Syphilis

Pathology.

The histological character of the lesions of meningo-vascular syphilis has already been described.

Spinal Pachymeningitis.

Syphilitic inflammation of the spinal dura mater may follow spread of infection from syphilitic osteitis of the spine or may occur independently of disease of the bone. The cervical region is usually involved—pachymeningitis cervicalis hypertrophica. It is probable that this condition is sometimes non-syphilitic. The dura mater is thickened and adherent to the arachnoid and pia. The vessels entering the cord are involved in the inflammation and the cord becomes sclerosed and may contain a central cavity. Destruction of the long tracts is followed by ascending and descending degeneration.

Meningo-myelitis.

As in cerebral syphilis the meninges and blood-vessels are both involved, though frequently not equally severely. When lepto-meningitis predominates, degenerative changes in the cord itself may be superficial, as in syphilitic amyotrophy. When the vessels also suffer severely, lesions of the substance of the cord are more extensive. Though the lesions are chronic, thrombosis of an important vessel may precipitate acute changes leading to an acute or subacute transverse lesion of the cord. In such cases the leptomeninges are adherent to the cord, which is visibly softened. Microscopically the vessels show endarteritis and perivascular cellular infiltration, and the meninges are also infiltrated. Within the cord there is degeneration of the myelin sheaths and sometimes also of the axis cylinders. The ganglion cells exhibit chromatolysis, and ascending and descending degenerations are to be found. Syphilitic myelitis usually involves the dorsal region of the cord and, though the leptomeninges may be extensively infiltrated, the area of softening of the cord is usually limited to two or three segments.

Erb's Syphilitic Spinal Paralysis.

Progressive spastic paraplegia developing during middle life was first described by Erb. This condition is probably usually a variety of syphilitic myelitis, though it is possible that syphilis may occasionally produce a primary degeneration of the pyramidal tracts. A similar progressive paraplegia was at one time ascribed to 'primary lateral sclerosis'. This is certainly not a nosological entity, and those cases which are not syphilitic in origin are probably due to disseminated sclerosis or subacute combined degeneration.

Spinal Endarteritis.

As in the brain, endarteritis of one of the spinal arteries or of its branches may be followed by thrombosis leading to a circumscribed area of softening within the cord, corresponding to the area of supply of the obstructed vessel.

Radiculitis.

One or more of the spinal posterior roots may be involved in syphilitic inflammation spreading inwards from the meninges.

Symptoms.

Cervical Pachymeningitis.

The earliest symptom is pain due to strangulation of the posterior roots, which radiates round the neck, over the shoulders, and down the upper limbs. The pains are followed by progressive atrophy of

the muscles supplied by the corresponding anterior roots. Finally, compression and ischaemia of the cord lead to progressive spastic paraplegia with sensory loss below the level of the lesion.

Amyotrophy.

Muscular atrophy is a rare symptom of spinal syphilis. Martin (1925) has reviewed the clinical features in sixty cases. The muscular atrophy may begin in the small muscles of the hands, in the shoulder muscles, or in the muscles on the outer side of the leg, and may be unilateral or bilateral. Pain in the affected region may occur at the onset and is sometimes severe. Spastic weakness of the lower limbs may develop, but is exceptional, and pupillary abnormalities are present in only a quarter of all cases.

Meningo-myelitis.

Myelitis is frequently an early symptom of meningo-vascular syphilis and not uncommonly occurs within three years of infection. The dorsal region of the cord is usually affected. Motor symptoms are generally preceded by pains in the back, spreading round the chest and abdomen. Weakness of the lower limbs develops between a few days and several weeks after the onset of the pains. In some cases complete flaccid paraplegia rapidly develops, with retention of urine and impairment or loss of all forms of sensibility below the level of the lesion. Sometimes the onset is more gradual and the functions of the cord are less severely affected. In such cases the patient develops spastic paraplegia-in-extension; control over the bladder is less severely impaired and sensory loss may be slight. In the flaccid form of paraplegia the reflexes in the lower limbs may at first be lost; extensor plantar responses shortly appear, however, and as spinal shock passes off, severe flexor spasms are likely to develop.

Erb's Syphilitic Spinal Paralysis.

Progressive spastic paraplegia is sometimes due to syphilis. It differs only from other forms of syphilitic myelitis in its more gradual onset and more slowly progressive course and the absence of sensory loss.

Spinal Endarteritis.

Endarteritis and arterial thrombosis play an important part in syphilitic myelitis. Exceptionally thrombosis of a branch of the anterior or posterior spinal arteries comparable with syphilitic cerebral thrombosis occurs. When a lateral branch of the anterior spinal artery is the site of thrombosis there is a sudden onset of weakness,

followed by wasting of the muscles innervated by the affected spinal segment. The spino-thalamic tract on the same side is frequently damaged, with the production of relative hemianalgesia and hemi-thermo-anaesthesia on the opposite side of the body, with an upper level a few segments below that involved in the lesion. When thrombosis of one posterior spinal artery occurs this is usually limited to a few segments. All forms of sensibility are likely to be impaired in the corresponding cutaneous segments owing to destruction of the posterior horn of grey matter. The posterior columns and the pyramidal tract on the same side are also the site of softening, as a result of which postural sensibility and appreciation of passive movement and of vibration are lost below the level of the lesion on the same side, and there is also spastic paralysis below the lesion on the side affected.

Radiculitis.

Syphilitic radiculitis usually affects the posterior roots and causes pain of a corresponding segmental distribution associated with either hyperalgesia or with analgesia. Herpes zoster is a not uncommon complication of this lesion. When the anterior roots are also affected, weakness and wasting develop in the muscles which they supply.

The Cerebro spinal Fluid.

In chronic spinal syphilis the changes in the cerebro-spinal fluid are the same as those found in cerebral syphilis; see p. 393. Following a subacute lesion, such as meningo-myelitis, there is frequently a considerable excess of protein and of mononuclear cells, and both in this condition and in syphilitic pachymeningitis leptomeningeal adhesions may lead to obstruction of the subarachnoid space, in which case the fluid will exhibit the changes characteristic of spinal block (see p 628). There is usually an excess of cells, however, and the Wassermann reaction is positive. A vascular lesion of the spinal cord may be associated with a normal spinal fluid, but the Wassermann reaction is usually positive in the blood.

Diagnosis.

Spinal syphilis has to be differentiated from other conditions causing paraplegia or irritation of posterior spinal roots, especially from spinal tumour and from disseminated sclerosis. The diagnosis usually is not difficult. A history of infection is usually obtainable. Signs of cerebral syphilis, especially irregularity of the pupils and impairment of their reaction to light, are frequently present and characteristic changes, especially a positive Wassermann reaction, are found in the cerebro spinal fluid.

Prognosis.

Spinal syphilis usually responds well to treatment, the determining factor in prognosis being the extent to which irreparable damage has already been done to the spinal cord. Even when myelitis has led to complete paraplegia, improvement is likely to occur as shock passes off and oedema of the cord disappears. Complete recovery, however, is not to be expected. The prognosis is naturally worse in patients who have developed urinary or cutaneous infections which may prove fatal. In amyotrophy the progress of the muscular wasting can frequently be arrested and slight improvement may occur, but much of the disability will be permanent. Root pains can usually be relieved, but are sometimes intractable.

Treatment of Meningo-vascular Syphilis.

Before treatment is begun the blood Wassermann reaction should be examined and a complete investigation of the cerebro-spinal fluid should be carried out for comparison with future findings. The object of treatment is the destruction of all the spirochaetes in the body, but few to-day are sanguine enough to believe that this can be accomplished, at least unless treatment is begun within a few weeks of infection. Even if this ideal cannot be attained, however, it is frequently possible to raise the patient's resistance to the infection so that it can be maintained in a state of latency. The most important spirochaeticidal drugs are mercury, bismuth, and the arseno-benzene derivatives. The action of the first two is gradual, that of the last is more intense but less enduring. The best therapeutic results are therefore obtained by using them in combination. Iodide is also valuable in promoting the absorption of inflammatory products.

Mercury.

Mercury may be given either by the mouth, by inunction, or by intramuscular injection. The preparations commonly employed for oral administration and their doses are

Hydrargyrum cum creta	.	.	.	gr. 1–2
Hydrargyri iodidum flavum	.	.	.	gr. ⅛
Pilula hydrargyri	.	.	.	gr. 1–3

Gastro-intestinal irritation may be controlled by giving simultaneously small doses of opium, such as pulvis ipecacuanhae co., gr. 1–2. These preparations are best given in the form of pills. Alternatively liquor hydrargyri perchloridi may be used in 1-drachm doses.

Inunction requires to be carried out by a skilled rubber. At each inunction 3 gm. of 33⅓ per cent. mercury ointment is rubbed into the skin. The course consists of from 40 to 200 rubbings, depending upon the patient's tolerance. For intramuscular injection the most

painless preparation is 10 per cent. mercury cream, the dose being 1 grain of mercury weekly.

Since mercury is apt to produce stomatitis, the teeth must be kept in good condition. Stomatitis is an indication that the limit of tolerance has been reached.

Bismuth

Bismuth is more strongly spirochaeticidal than mercury and of recent years has replaced the latter drug to a considerable extent. It is given intramuscularly as a suspension, either of the tartro-bismuthate of sodium and potassium, which is somewhat painful, or of the oxychloride or salicylate of bismuth, which causes little pain. The average dose is 0·3-0·5 gm. of bismuth weekly for a series of 10 injections. Bismuth, like mercury, may cause stomatitis and may produce a greyish-blue line on the gum margin.

Arseno-benzene Derivatives.

Salvarsan has been superseded by more convenient trivalent arsenical preparations, of which those in commonest use are neo-salvarsan, or novarsenobillon, silver salvarsan, and sulfarsenol. The first is given intravenously, the maximum dose being 0·9 gm. Silver salvarsan is also given intravenously in doses up to 0·3 gm. Sulfarsenol in doses of 0 6 gm. may be given intramuscularly or into the deep subcutaneous tissues. Pentavalent arsenical preparations such as tryparsamide, stovarsol, and acetylarsan are said to penetrate the nervous system more readily. The dose of tryparsamide is 1-3 gm. All of these drugs are usually given in courses of from 6 to 10 injections. They are contraindicated in the elderly, in those with advanced arterial disease, and when there is reason to suspect that the liver or kidneys are damaged. They should be given with caution in cases of cardio-aortic syphilis.

Iodide.

Iodide is usually well tolerated, but may cause gastro-intestinal disturbances or a rash and other symptoms of iodism. When well tolerated it should be given in increasing doses by the mouth, until the patient is taking 60-90 grains of potassium iodide a day, and this dose should be continued for several weeks. Smaller doses must be used for more prolonged administration. Thyroid extract appears to be of value in increasing the patient's resistance to the infection.

The Routine of Treatment.

Treatment should be given in a series of courses of an arsenical preparation and mercury or bismuth and iodide simultaneously. The course consists of a weekly injection of novarsenobillon for 6-8

weeks, beginning with 0·45 gm. and increasing to 0 9 gm. At the same time mercury is given, combined with iodide, by the mouth, or mercury or bismuth is injected intramuscularly. The patient then rests for two months, during which time he has no treatment or only small doses of iodide. The course of injections is then repeated, and so on.

The blood Wassermann reaction should be examined every six months and the cerebro-spinal fluid once a year. *The object to be aimed at is primarily the relief of symptoms and the arrest of the progress of the disease.* The latter can only be regarded as having been achieved when the cerebro-spinal fluid is normal, with a negative Wassermann reaction, and the Wassermann reaction in the blood is also negative. When this has been achieved the patient should be thoroughly examined clinically and the blood Wassermann reaction tested once a year for five years, but it is unnecessary to examine the cerebro-spinal fluid again unless fresh symptoms appear. *Frequently, however, patients in whom the clinical course of the disease* appears to be arrested continue to manifest a positive Wassermann reaction in the blood or in the cerebro-spinal fluid or in both. Such patients may benefit from a course of induced pyrexia produced by three or four intravenous injections of graduated doses of B. Coli vaccine (Pyrifer). Good results may be obtained by suspending the vaccine in a dose of novarsenobillon and thus injecting them intravenously at the same time If, in spite of treatment for two or three years, the patient remains 'Wassermann-fast' and his clinical condition is satisfactory, *further treatment is inadvisable.*

The Meinicke Clarification Reaction

The recently introduced Meinicke clarification reaction is a useful accessory to the Wassermann reaction in the diagnosis of syphilis It utilizes the capacity of a syphilitic serum to precipitate a colloidal suspension. It may be applied both to the blood and to the cerebro-spinal fluid. Nicole and Fitzgerald found the Meinicke a more sensitive test for the serum than the Wassermann reaction, while the Kahn was more sensitive than either when applied to the cerebro-spinal fluid.

GENERAL PARALYSIS

Synonym: Dementia paralytica.

Aetiology.

General paralysis was recognized as a clinical entity about a hundred years ago, though, as its name 'general paralysis of the insane' implies, it was at first regarded as a form of paralysis supervening in persons who had already become insane. In the

latter half of last century its relationship to syphilitic infection was established, though syphilis was then regarded as predisposing to general paralysis rather than as actually causing it, hence it was termed a 'parasyphilitic' or 'metasyphilitic' disorder. Noguchi, however, in 1911, first demonstrated the presence of spirochaetes in the brains of sufferers from general paralysis.

Many hypotheses have been proposed in explanation of the marked difference in the clinical features of general paralysis and cerebral meningo-vascular syphilis, notably the rapidly progressive course of the former and its failure to respond to treatment which effects' improvement in the latter. The most satisfactory explanation is that put forward by McIntosh and Fildes, according to whom in meningo-vascular syphilis the nerve-cells of the brain suffer secondarily to infection of the mesoblastic tissues, especially the blood-vessels, whereas in general paralysis spirochaetes penetrate through the blood-vessels and reach the nerve-cells, which their toxins directly affect. Not only is the resulting degeneration of the nervous elements irreparable, but the spirochaetes lying within the brain substance are beyond the reach of spirochaeticidal drugs which cannot pass through the blood-vessels. This theory leaves unexplained the different distribution of the spirochaetes in meningo-vascular syphilis and in general paralysis, the invasion of the nervous tissues in the latter presumably being due to constitutional or immunological factors which are not yet understood.

General paralysis is the disorder present in about five out of twelve sufferers from neurosyphilis. Males are more liable to it than females in the proportion of four to one. It usually develops between ten and fifteen years after infection, though the interval may be much shorter and exceptionally thirty or more years may elapse. It is rarely, however, that the incubation period is more than twenty years. It has been stated that its duration is inversely proportional to the age at which infection occurs. The first symptoms usually appear between the ages of 40 and 50.

In many tropical and subtropical countries where syphilis is rife general paralysis is almost unknown amongst the natives. This, however, cannot be due to a peculiarity in the infecting organism, since Europeans who acquire the infection from the natives are liable to develop it.

Alcoholism, mental strain, physical trauma, and an inherited neuropathic constitution have all been regarded as predisposing to the development of general paralysis, but the influence of these factors is difficult to assess. Kretschmer has pointed out that the majority of sufferers come of a cyclothymic stock which is associated with a pyknic (i e. short, thickset) physique.

Pathology.

Macroscopically the brain is shrunken, the convolutions being unusually well defined, and there is a compensatory hydrocephalus, both external and internal, but the atrophy is confined to the anterior two-thirds of the hemispheres. The pia-arachnoid is usually more opaque than normal, and the walls of the ventricles present a granular appearance due to ependymitis. Haemorrhagic pachymeningitis is sometimes present.

Microscopically changes are predominantly cortical and are found in the meninges, blood-vessels, and neurones. The leptomeninges show a diffuse infiltration with lymphocytes and plasma cells. Similar cells occupy the perivascular spaces of the small vessels and capillaries of the cerebral cortex, and there is usually evidence of new formation of capillaries. The ganglion cells of the cortex show a varying degree of degeneration, going on to complete disappearance. These changes are most marked in the molecular layer and the layers of small and medium-sized pyramidal cells. The deeper layers, including the large pyramidal cells, show slighter or sometimes more acute alterations. Demyelination of the fibres of the cortex, especially of the tangential fibres, is also present, frequently with a focal distribution. There is a proliferation of the glia, with the formation of both fibroglia and of giant glial cells. The microglia is also hypertrophied. Iron is present in large amounts both in the perivascular spaces and in the microglia.

These cortical changes are always diffuse, but the frontal and temporal regions usually suffer most severely. Similar changes are to be found in the basal ganglia and in the cortex of the cerebellum. It has been pointed out that there appears to be no relationship between the severity of the cortical degeneration and the degree of infiltration of the overlying leptomeninges. Spirochaetes are demonstrable in the cortex in some 50 per cent of cases, especially in the frontal region, and have sometimes been found within ganglion cells. In the 'Lissauer type' of general paralysis, localized cortical atrophy, a 'spongy state' and patchy demyelination of the white matter are found. The pathological changes of tabes may co-exist with general paralysis.

Aortitis is almost invariably present.

Symptoms.

Mental Symptoms.

The earliest symptoms are usually mental, and in the early stages they are frequently so slight as to be apparent only to those who know the patient well. It is important, therefore, always to obtain

a history from a relative or friend. The earliest mental change is usually an impairment of intellectual efficiency. The patient is unable to do his work as well as formerly. He loses the power to concentrate, and his memory becomes untrustworthy. His business inefficiency, however, is apparent to others, but not to himself, though exceptionally anxiety may be prominent and together with the other symptoms described may lead to a mistaken diagnosis of neurosis. As the condition progresses the patient's behaviour becomes more abnormal, and he is apt to become careless about his dress and personal appearance and about money, as a result of which he may throw large sums away in extravagance or in ill-judged speculations. Alcoholic excess and sexual aberrations are common at this stage. The commonest early mental changes are thus symptoms of dementia (see also p. 400), and this form of the disorder is sometimes described as the 'simple dementing type'.

The form taken by the mental disorder, however, doubtless depends upon the patient's mental constitution, and thus other clinical pictures are not uncommon. The grandiose form, though frequently regarded as typical, is less common than simple dementia. Patients of this type are euphoric and develop delusions in which they figure as exceptional persons endowed with superhuman strength, immense wealth, or other magnificent attributes. They readily act on these delusions and may order large quantities of goods or write their physician a cheque for a million pounds, and they see no discrepancy between their imaginary attributes and their debilitated and unfortunate actual condition. Other emotional states may dominate the picture, leading to so-called depressed, agitated, maniacal, and circular types. Sometimes the condition closely resembles Korsakow's psychosis. As the patient becomes worse, however, the symptoms of dementia become more prominent, and in the terminal stage there is little evidence of any mental activity, and the sufferer, bedridden, incontinent, and dirty, leads a vegetative existence.

Speech exhibits a degradation parallel with that of other mental activities and suffers both in its receptive and expressive functions. Difficulty in naming objects is common. Echolalia may occur.

Physical Symptoms.

Epileptiform attacks occur in approximately 50 per cent. of cases. They may take the form of localized convulsions, without loss of consciousness; generalized attacks, in which consciousness is lost; or petit mal, in which brief impairment or loss of consciousness occurs without a convulsion. Status epilepticus sometimes occurs.

Apoplectiform attacks, so-called 'congestive attacks', are not

uncommon and such an episode may bring the patient under observation. The resulting symptoms, of which hemiplegia is the commonest, but which include aphasia, apraxia, and hemianopia, are always transitory and the associated loss of consciousness is usually brief. Recovery from an apoplectiform attack is often complete in a week or two.

Although in most cases physical abnormalities are present when the patient first comes under observation, it is important to recognize that they may be absent when mental changes are conspicuous. The expression is often vacant or fatuously smiling, sometimes somewhat mask-like. The pupils are usually contracted and irregular and react sluggishly to light. Typical Argyll Robertson pupils are often found. Optic atrophy is not uncommon, but is rarely severe enough to cause marked loss of visual acuity.

Voluntary power becomes progressively impaired, and weakness is usually associated with tremor, which is most conspicuous on voluntary movement and is best seen in the facial muscles, especially the lips and the tongue, and in the outstretched fingers. The slow slurred speech is highly characteristic. In addition, inco-ordination usually develops during the later stages, rendering the gait unsteady and the movements of the upper limbs ataxic.

Owing to bilateral degeneration of the pyramidal tracts, the tendon reflexes are usually exaggerated, the abdominal reflexes diminished or lost, and the plantar reflexes extensor. The association of tabes with general paralysis—so-called 'tabo-paresis'—however, is not uncommon, and in such cases the tendon reflexes are lost. Except in tabo-paresis, when the sensory changes characteristic of tabes are present, sensation is unimpaired in general paralysis. A loss of control over the sphincters is common at a comparatively early stage, but is then the outcome of the mental deterioration and not of a disorder of innervation at lower levels.

Syphilitic aortitis is common, but rarely causes symptoms. There is usually a progressive loss of body weight.

The cerebro-spinal fluid exhibits characteristic changes of great diagnostic importance. The pressure is frequently somewhat increased. There is usually an excess of cells, which are mononuclear, but the cell count rarely exceeds 100 per c.mm. The protein content is also increased and usually lies between 0·05 and 0·10 per cent. Marked increase of globulin is found and the globulin content of the fluid may be as high as one-third of the protein content (Hewitt). Lange's colloidal gold curve is of the paretic type, e.g. 5554311000 or even 5555555444. Exceptionally, though the curve remains of this type, precipitation is not quite complete and the highest figure is 4. The colloidal benzoin test yields a positive result, precipitation

being complete in the first five tubes, sometimes even in all ten. The Wassermann reaction is positive in the cerebro-spinal fluid in 100 per cent. of cases, and in the blood in from 90 to 100 per cent.

Diagnosis.

The constancy of serological abnormalities in the blood and cerebro-spinal fluid in general paralysis is of the utmost diagnostic importance, as it frequently confirms a diagnosis which on clinical grounds alone might be doubtful. In all cases, therefore, in which general paralysis is a possibility these tests should be carried out.

The mental symptoms in the early stage may simulate neurosis or manic-depressive psychosis. Neither of these conditions, however, is associated with signs of organic disease in the nervous system.

General paralysis must be distinguished from the presenile and senile dementias. In arteriosclerotic dementia the pupils may be contracted and tremor and extensor plantar responses may be present. In such cases the diagnosis can be made only after an examination of the blood and cerebro-spinal fluid.

Alcoholic dementia—'alcoholic pseudo-paresis'—may closely simulate general paralysis and may be distinguishable only by serological tests.

It is often difficult to distinguish from general paralysis meningo-vascular syphilis when this condition is associated with severe mental changes, since the Wassermann reaction may be positive in both blood and cerebro-spinal fluid in both conditions. When the colloidal gold curve in the fluid is of the luetic type this is a point in favour of meningo-vascular syphilis, but a paretic curve is not pathognomonic of general paralysis. In some cases only the response to treatment will settle the question. An improvement in the state of the cerebro-spinal fluid after vigorous antisyphilitic treatment with drugs would indicate that the condition was meningo-vascular, but in doubtful cases there should be no delay in treating the patient with malaria.

Prognosis.

Before the introduction of malarial treatment general paralysis was invariably fatal, and it was exceptional for a patient to survive more than three years. Exceptionally the disease runs a rapid course and proves fatal within a year. Remissions, which, however, are only temporary, occur spontaneously in from 10 to 20 per cent. of cases. Malarial treatment, the results of which are discussed below, has considerably improved the outlook. Nevertheless, even by this and other pyrexial methods less than half of all sufferers can be

restored to normal mentality and the results are often disappointing. The earlier the stage at which the diagnosis is made and treatment is begun the better the outlook.

Treatment.

Malarial Therapy.

The introduction of infection with malaria by Wagner-Jauregg in 1917 was a great advance in the treatment of general paralysis; and although other infections and various pyrexia-producing drugs have since been employed, the results have not equalled those obtained with malaria, though equally good results have been claimed for pyrexia produced by physical agents The cause of the beneficial action of malaria is still undecided. It has been suggested that the resulting pyrexin is the principal therapeutic factor, that antibodies to the malarial parasite are also effective against the spirochaetes, and that an increased permeability of the capillaries permits antibodies already present in the blood to penetrate to the spaces around the nerve-cells and reach spirochaetes which were previously protected from their action. Histologically, after treatment with malaria spirochaetes disappear from the brain and the inflammatory exudate diminishes. Some observers have described the development of miliary gummas, which they interpret as indicating increased immunity.

Methods of Inoculation.

The parasite of benign tertian malaria (P. vivax) is usually employed, and unless the source of infection is reliable, the donor's blood should first be examined microscopically to exclude the risk of infection with the malignant parasite (P. falciparum) which is dangerous. The patient may be inoculated by the bite of an infected mosquito, and such mosquitoes can be obtained in England from the Ministry of Health. At neurological hospitals, however, there are usually sufficient patients under treatment to enable transmission to be kept up from case to case, though this method is less satisfactory than direct mosquito inoculation. The donor's blood is withdrawn from a vein at the elbow, preferably during the decline of the fever, from 1 to 5 c.c. being received into a syringe which contain a few drops of 5 per cent. sodium citrate solution to prevent clotting. If the donor and recipient are in the same building the blood requires no further treatment, but should be injected without delay. The injection is usually made subcutaneously; but intramuscular, intracutaneous, and intravenous routes may be employed, the last-named yielding the shortest incubation period.

When the blood has to be sent a distance the malarial parasite

will live for twenty-four hours if the blood is citrated and kept at
body temperature, or the blood may be citrated and the red cells
washed by repeated centrifugalization with Ringer's solution, and
kept in a volume of Ringer's solution equal to that of the original
plasma, preferably at a low temperature, from $2°$ to $10°$ C., the test-
tube containing the blood being surrounded by ice. Alternatively
the blood may be defibrinated by shaking it with glass beads and
then placed in another test-tube which is similarly surrounded with
ice

Course of Induced Malaria.

The incubation period is extremely variable, ranging from two or
three days to seven weeks. Usually after subcutaneous injection
it is about ten days. The patient is allowed to have a number of
rigors, usually ten, unless it becomes necessary to terminate the
infection earlier. The infection is terminated by the administration
of quinine. Ten grains of quinine bisulphate may be given in solu-
tion or in cachets twice daily for three days and once daily for a
fortnight   Slight jaundice is not uncommon during the malaria.
Occasionally severe cardiac failure occurs. This requires appro-
priate treatment and is an indication for terminating the infection.
Digitalis may be given prophylactically during the treatment. Excep-
tionally also malaria may lead to an exacerbation of the mental
symptoms or to the development of severe mental confusion, agita-
tion, or, occasionally, acute mania. Malarial therapy is unsuitable
for very debilitated and for senile patients and for those with marked
cardio-vascular disease.

Results of Malarial Treatment.

The treatment itself is not without risk, though, according to
Weygandt, the immediate mortality should not exceed 5 per cent.
Many thousands of patients have now been treated and the results
indicate that 20 to 30 per cent. recover sufficiently to follow an
occupation. A similar proportion improve considerably, but not
sufficiently to return to work. Without malarial treatment only
about 10 per cent. have remissions, which are almost invariably
temporary. Meagher (1929) has compared two large groups of
treated and untreated cases in English mental hospitals. Nearly 90
per cent. of those who did not receive malarial treatment were dead
within four years, and only 3·4 per cent. had been discharged,
whereas of those thus treated only 34 per cent. were dead and 25·3
per cent. had been discharged. The best results were obtained with
early cases, and Wagner-Jauregg claims that complete remissions
could be obtained in all cases treated sufficiently early.

Patients with grandiose delusions appear to do best, while those with marked depression and juvenile paretics do worst.

The full results of malarial treatment are not apparent for several months after its termination, and not uncommonly the patient's mental state temporarily becomes worse. The principal change in favourable cases is in the mental state. Physical improvement is less conspicuous, though there is usually a gain in weight, associated with an increase in voluntary power and diminution or disappearance of tremor. No change usually occurs in the reactions of the pupils or in the condition of other reflexes. Improvement frequently occurs in the condition of the cerebro-spinal fluid and, as Nicole and Fitzgerald (1931) have shown, the full extent of the serological improvement cannot be estimated for several years There is usually a marked reduction in the pleocytosis in the fluid and in its globulin content. The paretic colloidal gold curve shows a tendency to become more normal, the degree of precipitation in lower dilutions becoming less. The Wassermann reaction becomes less strongly positive and may even become negative. In Nicole and Fitzgerald's series before treatment the Wassermann reaction was positive in the fluid in 100 per cent. of cases and in the blood in 89 per cent. After treatment it was positive in the fluid in 66·7 per cent. and in the blood in 70 per cent.

Other Methods of Treatment.

Besides malaria, other pyrexia-producing agents have been used in the treatment of general paralysis, including electro-pyrexia, the Kettering hypertherm, the intravenous injection of typhoid or B. Coli vaccine, and the intramuscular injection of sulphur. Sulphur is employed as a 1 per cent. suspension in olive oil. Graduated doses, beginning with 1 c c. and increasing by 1 c.c., are injected intramuscularly on the outer side of the thigh on alternate days until a dose of 10 c.c. is reached. The resulting rise of temperature takes from eight to twelve hours to develop, and there is usually considerable pain at the site of the injection. It is claimed that diathermy and hyperthermy yield results as good as, if not better than, malaria, but they need considerably more supervision. Tryparsamide given intravenously in weekly doses of 2 gm. is claimed to give better results in general paralysis than other arsenical preparations, and some authorities recommend a course of tryparsamide before malarial infection. A course of tryparsamide is frequently given after the termination of the malaria, since it is possible that the cerebral capillaries are less impermeable than normally to the drug, which also assists in the destruction of the malarial parasite. Some workers, however, believe that it may diminish the good effects of malaria.

Early cases of general paralysis, especially those characterized by simple dementia, can usually be treated at home, if suitable nursing is available, or in a nursing home. Those with more severe mental symptoms will require to be treated in a mental hospital. Adequate medical supervision is necessary for a long time in those who do well, and patients who return to positions of responsibility must be carefully watched, and the cerebro-spinal fluid examined annually for evidence of deterioration. A relapse may be treated by a second infection with malaria, but the results are usually not as good as after the first treatment.

TABES DORSALIS

Synonym: Locomotor ataxia.

Aetiology.

Tabes was first recognized as a clinical entity by Romberg and Duchenne. Its association with syphilis was first suspected by Fournier, and was established by the introduction of the Wassermann reaction and by the discovery of spirochaetes in the brain and spinal cord of affected individuals by Noguchi and by Marinesco and Minea. Tabes, like general paralysis, differs from meningo-vascular syphilis in respect of the systematized character of the spinal lesions and in the less satisfactory response of advanced cases to treatment. The various theories which have been brought forward to explain this difference are discussed in connexion with general paralysis.

As in the case of general paralysis, it is not uncommon to find that tabetic patients deny having had a primary chancre and the secondary manifestations of syphilis. These indications of infection may, therefore, be absent or so slight as to pass unnoticed. Tabes affects males much more frequently than females, and is the disorder present in 3 out of 12 cases of neurosyphilis. Although trauma has sometimes been blamed for precipitating the onset of symptoms, it is unlikely that it has this effect, but the patient in whom tabes is already developing may be able to compensate for his ataxia until he is confined to bed by an injury, when he temporarily loses this power, as a result of which inco-ordination is conspicuous when he gets up. Tabetic symptoms usually appear between eight and twelve years after infection. Exceptionally they may develop within three years, or their onset may be delayed until after twenty years or even longer. The age of onset usually lies between 35 and 50 years.

Pathology.

Macroscopically there is evidence of atrophy of the posterior spinal roots, especially of those in the lower thoracic and lumbo-sacral

regions. The dorsal columns of the spinal cord are flat or even sunken; hence the name tabes dorsalis or dorsal wasting. On section of the cord the posterior columns appear grey and translucent, in contrast to the normal appearance of the rest of the white matter.

Microscopically the essential lesion is a degeneration of the exogenous fibres of the cord, that is, of the central processes of
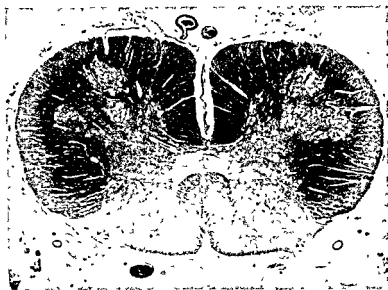
Fig. 43. Tabes dorsalis. Section of spinal cord.

the posterior root ganglion cells, which themselves are usually little affected. Since the only exogenous fibres which possess a long course within the cord are situated in the posterior columns, these exhibit a selective degeneration and their demyelination is conspicuous, stained by stains for myelin (Fig. 43). The endogenous fibres in the cornu-commissural zone, the region of the posterior columns lying just posterior to the grey commissure, usually escape. The incoming fibres earliest affected are those which in the thoracic region constitute the middle-root zone of the posterior columns or the bande-lette of Pierret. Since the lower thoracic and lumbo-sacral roots are first attacked and their fibres entering the posterior columns shift towards the middle line as they ascend the cord, the column of Goll suffers earlier than the column of Burdach in the cervical region. The latter, however, is affected later. There is secondary neuroglial proliferation in the posterior columns and the overlying pia mater

is somewhat thickened. Exceptionally, degeneration of anterior horn cells may occur in certain segments, in which case there is atrophy of the fibres of the corresponding anterior roots.

Many theories have been proposed in explanation of the selective character of the degenerative lesions of tabes in the spinal cord. The view of the older pathologists, and that adopted by Spielmeyer to-day, is that tabes is due to a primary degeneration of the exogenous fibres within the cord. Obersteiner and Redlich believe that degeneration is due to compression of the posterior root fibres by meningeal constriction at a point at which they pass through the pia mater Hassin considers that proliferation of the arachnoid leads to the retention of lymph within the tissue spaces of the cord. Nageotte and Richter believe that the essential lesion is syphilitic inflammation of the radicular nerve, while Orr and Rows incriminate action of syphilitic toxins upon the posterior roots. No satisfactory explanation has been given as to why a primary degeneration of the exogenous fibres of the cord should occur, and theories which place the lesion in the radicular nerve fail to explain the escape of the motor fibres. On the whole, Obersteiner and Redlich's theory appears the most plausible.

Optic atrophy is common and occurs in two forms, the degeneration of the nerve fibres being either primary or secondary to syphilitic inflammation of the interstitial tissues. The Argyll Robertson pupil has been variously explained. The loss of the pupillary reaction to light has been plausibly ascribed by Wilson to interruption of the reflex arc by syphilitic toxins in the neighbourhood of the upper part of the aqueduct of Sylvius, and he attributes the contraction of the pupils to damage to the descending oculo-sympathetic pupillo-dilator fibres in the same region. Sensory fibres of the cranial nerves, especially the trigeminal and glossopharyngeal, like those of the posterior roots, may exhibit degeneration as they approach the brain-stem, and degenerative changes have also been described in the afferent fibres of the sympathetic. The pathological changes of meningo-vascular syphilis are not uncommonly associated with tabes, and those of general paralysis may also be found.

Tabes is the most frequent cause of arthropathy—Charcot's joints According to Moritz, the earliest change in the joint is a hyperplasia of the cartilage. Later, destruction of the cartilage and erosion of the epiphysis occur and are often associated with the development of osteophytic outgrowths. There is an increase in the volume of the synovial fluid, and subluxation of an affected joint is not uncommon. Trauma frequently plays a part in the production of arthropathy. Syphilitic aortitis is a common complication of tabes

Symptoms.

The principal symptoms of tabes are readily interpreted as a result of the degeneration of the afferent fibres of the posterior roots. Pains and paraesthesiae are attributable to an irritable state of the degenerating sensory fibres. Sensory loss, i e analgesia and impairment of postural sensibility and appreciation of vibration, are due to interruption of the corresponding sensory fibres. Ataxia is due in part to impairment of appreciation of posture and passive movement, in part to interruption of afferent fibres conveying impulses concerned in co-ordination which do not reach consciousness. Diminution and loss of the tendon reflexes are due to interruption of their reflex arcs on the afferent side. Impotence and sphincter disturbances are the result of a similar loss of afferent impulses concerned in sexual function and in the evacuation of the bladder and rectum.

Mode of Onset.

The onset of tabes is usually gradual and insidious, but exceptionally it is rapid and the patient may become grossly ataxic within three months. Usually sensory symptoms, especially pain, precede *ataxia for months or years, but ataxia may develop early*, and a distinction between pre-ataxic and ataxic stages, though useful, is not universally applicable Frequently the early sensory symptoms are so slight that the patient does not come for treatment until a more serious symptom develops Hence the symptom which brings him to the doctor may be ataxia, vomiting, impotence, disorder of micturition, failing vision, diplopia, or even arthropathy.

Sensory Symptoms.

Pain is the most characteristic early symptom and usually takes the form of so-called 'lightning pains'. These pains, which are stabbing in character, occur in brief paroxysms in the lower limbs and may be very severe. As a rule they do not radiate longitudinally along the limb, but are localized to one spot, where the patient experiences a sensation as though a sharp object were being driven into the limb. Each attack lasts only a few seconds, but attacks may recur repeatedly in the same place, or may shift from place to place in the limb. A fresh attack of lightning pains may be precipitated by a change in the weather. They are usually worse when the patient is constipated. A pyogenic infection, such as an alveolar abscess, may lead to a severe exacerbation. It is not uncommon to find vaso-dilatation of the skin in the region to which the pains are referred, and in severe cases ecchymosis may occur. Similar severe paroxysmal pains may occur in the upper limbs or in the distribution

of the trigeminal nerve. Other forms of pain may be experienced, such as burning or tearing pains in the feet, pain in the distribution of the sciatic nerve, resembling sciatic neuritis, and a constricting pain around the chest or abdomen—'root pains'.

Paraesthesiae are not uncommon, especially in the lower limbs. The patient may complain that the feet feel numb or cold, and a sensation as of walking on wool is a common complaint. The skin of the trunk and lower limbs is frequently hypersensitive to touch and to heat and cold. The patient may be aware that certain parts of the body are anaesthetic. Thus he may be unable to feel the chair upon which he sits, and he may notice that he is unaware when his bladder is full and that he is unconscious of the act of defaecation. Giddiness may occur as a result of impairment of postural sensibility in the lower limbs.

Objective Sensory Changes.

The forms of sensibility which are first impaired are usually those which are mediated by the posterior columns. In particular, appreciation of vibration suffers early and usually before recognition of posture and passive movement. As a rule these forms of sensibility are affected in the lower limbs before the upper, though exceptionally the upper limbs suffer first—so-called 'cervical tabes'.

Painful sensibility is also early impaired, the deep tissues becoming insensitive to pain before the skin. Forcible compression of the muscles and of the tendo Achillis evokes no pain, and painful sensibility is frequently lost in the testicles. Cutaneous painful sensibility is not uniformly impaired, but is usually first lost in certain situations, namely, the side of the nose, the ulnar border of the arm and forearm, the region of the trunk between the nipples and the costal margin, the outer border of the leg and dorsum and sole of the foot, and the region surrounding the anus. In these regions, even when pin-prick is appreciated as painful, there is often a long delay, which may reach several seconds, between the application of the stimulus and its perception. Cutaneous sensibility to light touch, heat, and cold is usually unimpaired until a late stage, but finally there may be a diffuse loss of all forms of sensibility, extending over the whole of the body.

Ataxia.

Ataxia is due partly to loss of postural sensibility and partly to loss of 'unconscious' afferent impulses concerned in the regulation of posture and movement. The importance of the latter factor is well seen in patients who exhibit considerable ataxia of the lower limbs without detectable impairment of postural sensibility or of apprecia-

tion of passive movement. Ataxia usually begins in the lower limbs and at first is evident only as slight unsteadiness in walking and turning. Since the patient is able to some extent to compensate for absence of vision for the deficit of afferent impulses from his lower limbs, his ataxia becomes worse in the dark or when he closes his eyes, whence arises the characteristic symptom of falling into the basin, when the eyes are closed in washing the face. As the ataxia increases, movements of the lower limbs become increasingly incoordinate. The patient walks with a wide base, the feet are lifted too high and brought down to the ground too violently. Walking becomes impossible without a stick, and finally he can only walk if he is supported on both sides. The ataxia is equally evident when the patient is lying in bed and can be elicited by asking him to place one heel upon the opposite knee. Voluntary movement of the lower limbs against resistance is jerky and irregular, and when the patient is lying at rest irregular, jerky, involuntary movements can often be observed, especially in the feet and toes.

In the early stages ataxia of the lower limbs is best demonstrated by asking the patient to stand with the toes and heels together and the eyes closed, and watching whether he sways—Romberg's test—or by asking him to walk along a line placing one heel in front of the opposite toe.

In severe cases the trunk muscles also become ataxic and the patient may then be unable to sit up in bed without support. Ataxia of the upper limbs is manifest in the clumsiness with which fine movements of the fingers are performed and in special tests, such as the finger-nose test. The defective maintenance of posture may often be demonstrated in the outstretched fingers by asking the patient to close his eyes. When the posture of the fingers is no longer controlled by vision they slowly droop, and irregular, so-called 'piano-playing' movements may occur.

Muscle Tone

Deficiency of the afferent impulses from the muscles upon which muscle tone depends leads to muscular hypotonia, as a result of which exaggerated passive movements of the joints become possible, for example, an extreme degree of flexion of the hip with the knee extended.

The Reflexes of the Limbs and Trunk.

Degeneration of the afferent fibres concerned in the tendon reflexes leads to their diminution and ultimately to their disappearance. The ankle-jerks are thus affected before the knee-jerks, and it is not uncommon to find the reflexes unequal on the two sides. The tendon-

jerks of the upper limbs are usually diminished at an early stage, but are finally lost only after those of the lower limbs have disappeared. The plantar reflexes usually remain elicitable and are flexor, except in those rare cases in which pyramidal degeneration is present, when they are extensor. The abdominal reflexes are also obtainable and are frequently unusually brisk.

Sphincter Disturbances.

Disturbances in bladder control may occur early when the sacral roots are early involved. When the lumbar roots suffer first, considerable ataxia of the lower limbs may precede bladder symptoms. The patient may complain either of difficulty of micturition or of incontinence. Catheterization not uncommonly reveals the presence of several ounces of residual urine, and complete retention may occur. Infection of the urinary tract develops sooner or later when the bladder is incompletely emptied, and ascending pyelo-nephritis may prove fatal. Constipation is the rule, but faecal incontinence may occur, especially when the patient is unconscious of the act of defaecation. Impotence is sometimes an early symptom ; in other cases it is absent, although the patient is ataxic.

Ocular Symptoms.

Pupillary abnormalities are present in a large proportion of patients when they come under observation and in more than 90 per cent at some time in the course of the disease. The pupils are usually contracted and frequently irregular. Exceptionally they are moderately or even widely dilated. Somewhat more frequently one is moderately dilated and the other contracted. The pupillary reaction to light is at first impaired and later lost, while that on accommodation-convergence is retained. The complete Argyll Robertson pupil, however, is often a late manifestation, and in the early stages it is commoner to find that the reaction of the pupil to light is present but reduced in amplitude, exhibits a latent period which is longer than normal, and is ill-sustained. The light reflex is often brisker in one eye than in the other, and the consensual reaction may be brisker than the direct. The contracted pupil fails to dilate in response to a scratch upon the skin of the neck, and both the myosis and the loss of the ciliospinal reflex are probably due to degeneration of the fibres of the oculo-sympathetic. A moderate degree of ptosis, probably also due to oculo-sympathetic paralysis, is common, and the compensatory action of the frontalis muscle by wrinkling the brow contributes to the characteristic facies. Diplopia is a common symptom and is usually due to defective balance of the ocular muscles. In the early stages it is transitory, but later per-

manent paralysis of the third or sixth nerve may develop. A bizarre dissociation of ocular movement may occur if one eye is allowed to fix an object while the vision of the other is obscured.

Optic atrophy is of the 'primary' variety. The optic disk is small and pale, the physiological cup is preserved, and the lamina cribrosa is often visible. The fundal vessels are usually reduced in calibre. Optic atrophy in tabes may be slight and non-progressive, giving rise to no subjective impairment of visual acuity and being discovered only on routine examination. When, however, the patient complains of failing vision the atrophy is likely to be progressive and to terminate in blindness. Usually visual acuity deteriorates first in the periphery of the visual fields; less often there is a central scotoma It is an old observation that when optic atrophy develops early, ataxia of the lower limbs does not usually become severe, and the development of the whole disorder is arrested.

Other Cranial Nerves.

Pain and analgesia in the distribution of the trigeminal nerve have already been described. Loss of smell and taste occasionally occurs. Degeneration of the eighth nerves may lead to deafness, and involvement of the vestibular fibres may cause vertigo. Exceptionally, degeneration of part of the nucleus ambiguus causes bilateral paralysis of the abductors of the larynx, and paralysis of the spinal accessory and hypoglossal nerves is occasionally observed.

Trophic Changes.

Arthropathies—Charcot's joints—are not uncommon. Their complete aetiology is not understood, though symptoms not infrequently appear after an injury. The onset of the joint change is frequently rapid, and there is considerable swelling, with increase in the synovial fluid. The skin may appear hot, but pain is almost invariably absent. Later, osteophytic outgrowths frequently develop around the joint, which thus becomes much increased in size, and considerable disorganization with subluxation may occur. Radiograms show as a rule marked erosion of the joint surfaces with formation of new bone at the articular margins or from the adjacent part of the shaft (Fig. 44). The knee is most frequently affected, and after that the hip. The shoulder, tarsal joints, elbow, ankle, small joints of the fingers and toes and spine are involved in approximately this order of frequency. The long bones are brittle, and fractures may occur as a result of slight trauma.

The commonest trophic change in the skin is the perforating ulcer, which is usually seen beneath the pad of the great toe or at other pressure-points on the sole (Fig. 45). The first stage is an epithelial

E e

thickening resembling a corn, and, either spontaneously or as a result of attempts to cut it away, an indolent ulcer develops. Sometimes a sinus extends deeply as far as the underlying bone, and considerable bony disorganization and deformity may result. Other trophic changes include the cutaneous ecchymoses already described, brittleness and falling out of the hair, and even exceptionally of the teeth.

Fig. 44. Radiogram of bilateral charcot hips in a tabetic patient.

Herpes zoster may occur, as in other conditions in which there is a lesion of the spinal posterior roots.

Tabetic Crises.

Paroxysmal painful disorders of function of various viscera occur in tabes and have received the name of crises. The gastric crisis is the commonest of these disturbances. It is characterized by attacks of epigastric pain associated with severe vomiting, and may last from a few hours to several days. Laryngeal crises consist of attacks of dyspnoea associated with cough and inspiratory and expiratory stridor. Rectal crises, characterized by tenesmus, and vesical crises, characterized by pain in the bladder or penis and strangury, may also occur, and renal and other crises have been described. The common feature of most tabetic crises appears to be increased motility of a hollow viscus, which is probably the result of a disorder of autonomic afferent impulses.

The Cerebro-spinal Fluid.

The pressure is frequently somewhat above normal. There is usually an excess of cells, which are mononuclear and do not often exceed 70 per c.mm. The protein may be normal or slightly increased. There is an excess of globulin in 90 per cent of cases. The colloidal gold curve is usually of the 'luetic' type. A 'paretic' curve,

Fig. 45. Perforating ulcers of the left foot; scars of former ulcers on the right foot

even in the absence of symptoms of general paralysis, should suggest the possibility of this complication developing later The Wassermann reaction is positive in both blood and cerebro-spinal fluid in 65 per cent. of cases, positive in the fluid alone in 10 per cent , in the blood alone in 5 per cent., and negative in both in 20 per cent. The reaction may be negative in the fluid in spite of an excess of cells, protein, and globulin, and a negative reaction in both blood and fluid or indeed a completely normal fluid may be found in a patient in whom the disease is progressive.

Complications.

Symptoms of meningo-vascular syphilis, including muscular wasting, may coexist with those of tabes, though this is unusual General paralysis may be associated with tabes. A tabetic patient may, after

a lapse of years, develop general paralysis, or the symptoms of tabes
may be present in an individual who comes under observation on
account of symptoms of this disorder. Apart from general paralysis,
psychotic reactions, often with a paranoid trend, are not uncommon
in long-standing cases of tabes. Syphilitic aortitis is not uncommon,
but rarely gives rise to symptoms. Chronic gastric ulcer occurs more
often than can be explained by chance and the symptoms may be
mistaken for gastric crises.

Diagnosis.

When the patient has reached the ataxic stage, diagnosis usually
presents little difficulty, for the characteristic physical signs are by
then well developed and the matter is clinched by investigation of
the blood and cerebro spinal fluid. In disseminated sclerosis ataxia
of the lower limbs is associated with spasticity, exaggerated tendon
reflexes, and extensor plantar responses. Friedreich's ataxia re-
sembles tabes in the association of ataxia of the lower limbs with
diminution or loss of the ankle-jerks, but this disorder usually begins
at an early age and is differentiated from tabes clinically by the
presence of nystagmus, dysarthria, extensor plantar responses,
scoliosis, and pes cavus. Polyneuritis may simulate tabes when there
is pronounced ataxia of the lower limbs. In alcoholic polyneuritis
the pupillary reactions may be sluggish, the tendon reflexes are
diminished or lost, the lower limbs are frequently ataxic, pains occur
in the limbs, and there is an impairment of postural sensibility. In
this condition, however, weakness of the peripheral muscles of the
limbs is conspicuous and wrist- and foot-drop are often present, and
the deep tissues, especially the muscles, are tender on pressure and
not, as in tabes, analgesic.

When ataxia is absent the prominence of some other symptom
may lead to a mistake in diagnosis, for example, pains in the limbs
may be attributed to arthritis, root pains in the trunk to lesions of
underlying viscera, gastric crises to ulceration of the stomach or
duodenum, disturbances of the vesical sphincter to enlarged prostate
or lesions of the bladder, arthropathy to arthritis, facial pain to
trigeminal neuralgia, and optic atrophy to toxic amblyopia. These
mistakes can only be avoided by systematic examination of the
nervous system, special stress being laid upon the pupillary reflexes
and upon diminution, absence, or inequality of the tendon reflexes in
the lower limbs, especially the ankle-jerks. In doubtful cases the
blood and cerebro-spinal fluid should be examined. It must always
be borne in mind that tabes may co-exist with other disorders. All
patients suspected of gastric crisis should have a barium meal, as
the failure to diagnose a gastric ulcer in a tabetic may be far more

disastrous for the patient than to mistake a gastric crisis for an organic lesion of the stomach.

Prognosis.

Tabes is extremely variable in its rate of progress and in the extent to which it responds to treatment. A rapidly progressive course with the development of ataxia in a few months is rare. Usually the duration of the pre-ataxic stage lies between two and five years. In some cases ataxia never develops to a serious extent and one encounters abortive forms with signs such as Argyll Robertson pupils and absent knee- and ankle-jerks, but no symptoms. The rate at which ataxia is likely to increase can be roughly assessed from the duration of the pre-ataxic stage. The longer this is, the slower is likely to be the subsequent progress of the disorder. The response to treatment is equally variable. Sometimes considerable improvement occurs and the disorder appears to be arrested. Other patients go downhill rapidly or slowly in spite of all treatment. Optic atrophy is not necessarily progressive, but when progressive invariably terminates in blindness. Gastric crises not infrequently respond satisfactorily to the general treatment of tabes, and perforating ulcers which are not too far advanced can usually be induced to heal. No improvement can be expected in the bony changes associated with arthropathy. Improvement frequently occurs in sphincter control, and impotence, though often permanent, is not necessarily so, for sexual power may return after treatment. In fatal cases death usually occurs from infection of the urinary tract, from syphilitic infection of the heart and aorta, from supervening general paralysis, or from some intercurrent disease.

Treatment.

General Treatment.

The tabetic patient must be enjoined to avoid excessive fatigue and indulgence in alcohol. Special attention should be paid to the care of the bowels on account of the liability of the tabetic to constipation, which intensifies the pains.

Vigorous antisyphilitic treatment must be carried out along the lines indicated for meningo-vascular syphilis. The intrathecal injection of salvarsanized serum, the Swift-Ellis treatment, is of value in intractable cases. The patient receives a dose of an arsenical compound intravenously and one hour later 50 c.c. of blood are withdrawn with aseptic precautions. The blood is allowed to clot and, after centrifuging for 30 minutes, the clear supernatant serum is pipetted off and diluted with an equal volume of sterile normal saline. About 40 c.c. of the diluted serum is injected either into the

cisterna magna or into the lumbar subarachnoid space. Malaria, employed as in the treatment of general paralysis, is a valuable adjunct to treatment in suitable cases. It should be reserved for patients in whom the course of the disorder is rapidly progressive in spite of the usual antisyphilitic treatment and for those in whom particular symptoms, such as severe pains, prove otherwise intractable. It sometimes gives brilliant results. One of my patients, who became grossly ataxic in a few months, could only walk when supported on both sides and showed no response to antisyphilitic treatment with drugs, so far recovered after malaria as to be able to return to his work, walking with a stick, an improvement which has been maintained for nine years. Malaria may be used in an attempt to avert blindness from optic atrophy, but I have never known it successful.

Treatment of Special Symptoms.

Pain. Tabetic pains are usually ameliorated by the coal-tar analgesics. When they are severe, however, they can only be relieved by morphine, which is debarred on account of the risk of addiction. They can sometimes be checked by the intravenous injection of hypertonic saline solution, for example, 70 c.c. of 15 per cent. sodium chloride, and this can be repeated as required. Induced pyrexia is also valuable in some cases, typhoid vaccine being injected intravenously, suspended in a solution of novarsenobillon; see p. 401. When this fails, relief may be obtained from X-ray irradiation of the spinal cord and posterior roots or from chordotomy.

Ataxia. Co-ordination of the limbs may be improved by suitable re-educational exercises on the lines of those first suggested by Fraenkel.

The Bladder. Precipitancy of micturition may be relieved by belladonna in doses of 5 minims of the tincture or $\frac{1}{4}$ grain of the dry extract three times a day. Catheterization should always be carried out to determine whether there is any residual urine. When this is present the urine should be kept acid by means of suitable doses of sodium acid phosphate. Hexamine is frequently irritating and is unnecessary. If residual urine regularly amounts to more than two or three ounces, daily catheterization should be carried out *in the hope that evacuation of the bladder may become more complete*. The risks that infection of the bladder will follow repeated catheterization must, however, always be weighed against the disadvantages of residual urine. Infection of the urinary tract will require appropriate treatment.

Crises. Patients subject to gastric crises should take a bland, non-irritating diet, together with bismuth and alkalies. A crisis can

frequently be cut short by the subcutaneous injection of 10 minims of 1 in 1,000 adrenalin. If this fails, morphine and atropine may be tried. In severe cases benefit has followed section of the lower thoracic spinal posterior roots, and the corresponding sympathetic rami, though the results of this operation are uncertain.

Rectal crises can often be prevented by adequate care of the bowels. When they occur they should be treated by a saline enema, followed by a suppository containing 2 grains of chloretone.

Laryngeal crises are best treated by the inhalation of amyl nitrite or of a little chloroform, or by spraying the larynx with a 1 per cent. solution of cocaine.

Perforating Ulcer. Tabetic patients should wear ill-fitting boots and should be warned against cutting their corns, on account of the risk that a perforating ulcer may follow a slight injury. When an ulcer has developed, the foot must be rested, and the thickened epidermis should be softened by repeated hot fomentations and carefully pared away with a sharp razor.

Arthropathy The object of treatment is to relieve the strain on the damaged joint. The knee and ankle should be supported by a leather corset strengthened with steel. When the hip is affected a Thomas walking caliper will be required. Spinal arthropathy necessitates a leather corset or spinal brace. When there is much fluid in the joint this may be aspirated. Excision of an arthropathic joint should not be attempted, since, on account of the existing trophic disorder, the result is likely to be unsatisfactory.

CONGENITAL NEUROSYPHILIS

Active neurosyphilis occurs in from 8 to 10 per cent. of congenitally syphilitic children, males being affected slightly more often than females (Jeans and Cooke). Neither in its pathological nor in its clinical features does congenital neurosyphilis differ in any essential respects from the acquired form. Both meningo-vascular and parenchymatous neurosyphilis occur. The intra-uterine infection of the nervous system with the spirochaete may lead to actual developmental arrest so that *the cerebral hemispheres are* unusually small. Gross disappearance of Purkinje cells with gliosis of the cerebellar cortex is rather characteristic of juvenile general paralysis.

Symptoms.

The meningo-vascular form is much commoner than the parenchymatous. Both mental deficiency and convulsions are common. Slight hydrocephalus is not rare, but the head does not attain the large size seen in idiopathic congenital hydrocephalus. Syphilitic

hydrocephalus appears always to be of the communicating type. Pupillary abnormalities are the most frequent disorders found within the region of the cranial nerves. The pupils are often irregular and unequal and the reaction to light is sluggish or absent. Optic atrophy is not uncommon and may arise in several ways. It may be secondary to choroido-retinitis or the result of involvement of the optic nerves or chiasma in basal syphilitic meningitis, or a degenerative process associated with congenital general paralysis or tabes. Facial weakness is frequently seen. Deafness, a common manifestation of congenital syphilis, is due in most cases to a lesion within the temporal bone and not to involvement of the eighth nerve in its intracranial course. Destruction of the pyramidal fibres may lead to diplegia or hemiplegia. Moderate degrees of infantilism are not uncommon. I have seen extreme infantilism of the Lorain type associated with optic atrophy as a result of basal meningitis in congenital syphilis. Narcolepsy and diabetes insipidus are rare manifestations.

Parenchymatous neurosyphilis is rare. Stewart estimates that general paralysis occurs in 1 per cent. of congenital syphilitics. The child may be mentally defective from birth but symptoms usually develop during the first half of the second decade of life. The symptoms are similar to those of the acquired form, though the mental symptoms are usually less florid and are those of acquired mental deficiency. Grandiose delusions, if present, are puerile in type; for example, a boy stated that he owned all the sweet shops in the country. The course of the disorder is somewhat slower than in the adult, and the patient may live for ten or more years.

Congenital tabes usually develops somewhat later in life than congenital general paralysis, and may not make its appearance until early adult life. Optic atrophy is common in both, and in both the pupils are often widely dilated and fixed.

The Wassermann reaction of the blood is usually positive when congenital neurosyphilis is progressive, but it may be negative in latent or arrested cases. The cerebro-spinal fluid usually shows the changes associated with the same forms of the acquired disorder, but in some cases of congenital meningo-vascular syphilis the Wassermann reaction may be negative in the cerebro-spinal fluid, although other changes, such as an increase in the globulin and a pleocytosis, are present.

Diagnosis.

The diagnosis is usually easy, since other signs of congenital syphilis are generally present, and is confirmed by the serological reactions of the child and its parents.

Prognosis.

The response to treatment is disappointing in patients who come under observation on account of the presence of nervous symptoms, especially in congenital general paralysis and tabes. Hence it is important that the cerebro-spinal fluid should be examined in all congenitally syphilitic children at an early age, in order that latent neurosyphilis may be detected.

Treatment.

Treatment should be carried out on the same lines as for acquired syphilis. Intravenous injections are difficult in infants, and the injection of arsenical preparations into the superior longitudinal sinus should be avoided as too risky. It is better to use sulfarsenol, which can be injected intramuscularly. Malaria should be used in the treatment of congenital general paralysis, but permanent mental improvement is very rare.

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CHAPTER X

VIRUS INFECTIONS OF THE NERVOUS SYSTEM

1. GENERAL CONSIDERATIONS

The Nature of Viruses.

THE term 'neurotropic virus' is used to describe minute filterable pathogenic agents which attack the nervous system. The first neurotropic virus, the causal organism of rabies, was discovered by Pasteur in 1884, and poliomyelitis was shown to be due to a neurotropic virus in 1909. During recent years the causal organisms of a number of other nervous diseases, both in man and in animals, have been found to be neurotropic viruses. *These include in man three varieties* of encephalitis, the Japanese type B, the St. Louis type, and the type known as Australian X disease, and acute lymphocytic chorio-meningitis. Two other diseases, encephalitis lethargica and herpes zoster, though they have never been transmitted to animals are regarded as almost certainly due to neurotropic viruses.

The links between human and animal disease are nowhere closer than in the realm of the neurotropic viruses. Rabies is always acquired by man from an infected animal. Acute lymphocytic chorio-meningitis is endemic among mice, which may be the source of human infection. Another neurotropic virus known as B virus, transmitted to man from monkeys, has caused two fatal cases of acute ascending myelitis. Viruses among animals are responsible for Borna disease of horses, dog distemper, fox encephalitis, equine encephalo-myelitis, and louping-ill of sheep. Recently human cases of acute encephalo-myelitis have been shown to be caused by the virus of equine encephalo-myelitis, which is known to be spread by mosquitoes. Louping-ill has caused several laboratory infections in man and it has been suggested that this virus may be the cause of the human encephalitis known as Australian X disease.

The neurotropic viruses possess a number of characteristics in common. They are invisible and usually pass through filter candles. They require special media for artificial cultivation, but survive for long periods in glycerol and in the dry state. They are destroyed by heat at relatively low temperatures, but they are resistant to cold. They are more susceptible to oxidizing agents, such as hydrogen peroxide and potassium permanganate than to ordinary disinfectants. The blood serum of the convalescent organism possesses the power of neutralizing a certain amount of the virus, but each virus is a specific antigen and no cross immunity exists between them.

Pathological Changes in the Nervous System. The viruses appear

to be obligatory intra-cellular parasites. They damage the nervous system, therefore, by directly attacking the ganglion cells. In very acute lesions there is necrosis of these cells. When the process is less acute, diffuse and focal microglial proliferation occurs and in some diseases inclusion bodies are found in the nerve cells. In many cases mesodermal changes such as perivascular cuffing and meningeal infiltration are a reaction to the inflammation, but some viruses invade both glial and mesodermal elements. The affinity of the neurotropic viruses is for the grey matter of the nervous system, hence they have been called polioclastic. There is no evidence that any of the primarily demyelinating diseases of the nervous system is directly due to a neurotropic virus. Hurst (1935, 1936) classifies the viruses which attack the nervous system in four groups. (1) The stricter neurotropes which attack directly and destroy nerve cells but are without obvious direct action on other cells. (2) The pantropic viruses type 1. While definitely neurotropic these also directly attack and produce specific lesions in cells derived from all embryonic layers. (3) The pantropic viruses type 2. These, although pantropic, possess cellular affinities which are more restricted than those of viruses of type 1 and outside the nervous system attack particularly the epithelial and blood vascular structures. (4) The viscerotropic viruses. These under natural conditions do not cause encephalitis and when inoculated directly into the brain cause primarily meningeal lesions. These differences are important in relation to the mode of infection of the nervous system. In group 1 in which are placed poliomyelitis and rabies the virus introduced at a local site passes up the peripheral nerves to the nervous system and does not cause disease when inoculated into a denervated area. These viruses are rarely found in the blood or cerebro-spinal fluid. Viruses of groups 2 and 3 may spread by the blood stream and then invade the nervous system by ascending the peripheral nerves. Transmission of neurotropic viruses along the course of nerve fibres both within the peripheral nerves and within the central nervous system is well established. It is probable that they travel along the axones.

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2. EPIDEMIC ENCEPHALITIS LETHARGICA

Synonyms: Epidemic encephalitis, type A; 'sleepy sickness'.
Definition: An epidemic disease probably due to a neurotropic virus with an acute, subacute or insidious onset and in most cases a

chronic course, and characterized pathologically by inflammatory and degenerative changes, especially in the grey matter of the mid-brain, and clinically in the acute stage by disturbance of the sleep rhythm, especially lethargy, and pupillary abnormalities, and in the chronic stage by the Parkinsonian syndrome.

Aetiology.

Encephalitis lethargica was first described by von Economo in May 1917, and about the same time by Cruchet, Moutier, and Calmette. It seems to have made its first appearance in 1915, though some authorities believe that epidemics of it can be recognized in medical history. Since 1915 widespread epidemics have occurred It affects the sexes equally and no age is exempt, though it is commonest in early adult life. There is a seasonal incidence, most cases occurring as a rule in the first quarter of the year. The occurrence of outbreaks in institutions and the occasional appearance of case-to-case infection indicate that the disease is contagious, though only feebly so. There is no evidence for its transmission by non-human agencies. Numerous attempts by bacteriologists to isolate a causative organism have failed, but there is little doubt that it is due to a filterable virus. Outbreaks of epidemic hiccup have coincided with epidemics of encephalitis lethargica, and it is possible that both are due to the same organism.

Pathology.

The macroscopic changes in the nervous system are slight, consisting, in the acute stage, of congestion, oedema, and sometimes petechial haemorrhages. Microscopically (Figs. 46 and 47) perivascular changes are conspicuous in the early stages. The smaller vessels are engorged and may exhibit perivascular cuffs or sleeves of inflammatory cells, chiefly lymphocytes and plasma cells. In addition the nerve tissue is diffusely infiltrated with mononuclear cells, and the nerve-cells themselves show degenerative changes. In the chronic stages the mesodermal elements show little evidence of reaction, but degeneration of nerve-cells continues. In the acute stage the brunt of the infection falls upon the grey matter of the upper part of the mid-brain, the region of the oculomotor nuclei, and the substantia nigra. The basal ganglia and the pons and medulla are affected next in frequency. No part of the nervous system is exempt, and the spinal cord may be diffusely affected. In the chronic stage also the degenerative changes are diffuse. The substantia nigra usually suffers severely, but the grey matter of the cerebral cortex and basal ganglia is also involved. The Parkinsonian syndrome, a common feature of chronic encephalitis lethargica, has been attributed to the destruction
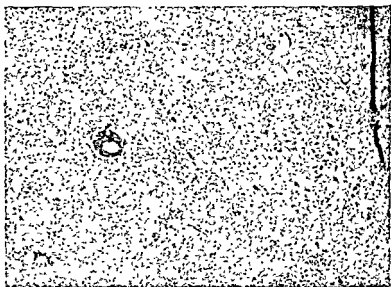
FIG. 46. Encephalitis lethargica. Substantia nigra showing perivascular and diffuse inflammatory infiltration. H.E. × 36.
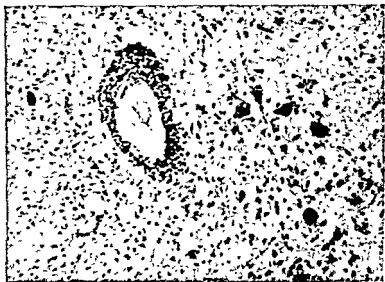
FIG. 47. The same. H.E. × 145.

of the cells of the substantia nigra, but in view of the widespread changes elsewhere in such cases it is difficult to relate the Parkinsonian syndrome to a lesion localized in one situation.

Symptoms.

The symptoms of encephalitis lethargica have changed remarkably in the twenty years during which it has been under observation. When it first appeared it was an acute disease, often with a fulminating onset. *After several years the acute stage became less severe and the chronic stage more prominent.* At the present day the acute stage is often so mild as to pass undetected, and may possibly sometimes be absent altogether, and the disease is coming to be regarded as primarily a chronic one. It is convenient, therefore, to consider separately the symptoms of the acute and those of the chronic stages.

SYMPTOMS OF THE ACUTE STAGE

The onset may be sudden or gradual. In the earlier epidemics it was often fulminating and characterized by headache, vertigo, delirium, convulsive and apoplectic phenomena, and severe pain in the trunk or limbs. To-day the onset is usually more gradual. The three most constant symptoms of the acute stage are headache, disturbance of sleep rhythm, and visual abnormalities, such as blurred vision or diplopia. The headache is usually not severe and may occasionally be accompanied by vomiting or by pain in the back or limbs. The characteristic disturbance of sleep rhythm is lethargy by day with insomnia or restlessness at night. The lethargy has been sufficiently constant, especially in the early cases, to contribute the epithet 'lethargica' to the name of the disease. *The patient can always be roused except when lethargy passes into coma. Neither lethargy by day nor insomnia by night is present in all cases.* Either may dominate the picture throughout the twenty-four hours. Delirium and fever occur only in the more severe cases.

Visual disturbances are important on account of their frequency. Papilloedema and optic atrophy are very rare. Pupillary disturbances are common. The pupils may be irregular and unequal. The reaction on accommodation is more often lost than that to light. The Argyll Robertson pupil is rare. Ptosis is frequent but usually slight. External ophthalmoplegia is common, and is probably often due to neuritis of the oculomotor nerve-trunks. The sixth is most often affected. Nuclear and supranuclear ophthalmoplegias are less common, but all forms of conjugate ocular palsy have been seen. The blurred vision of which the patient so often complains may be

due to paresis of accommodation or to paresis of an external ocular muscle. Diplopia is frequent.

Facial weakness is common and is almost always transitory. Vertigo is also common and is probably due to involvement of the vestibular tracts, the same lesion possibly causing the fine nystagmus which is often present. Bulbar symptoms are rare, and so too are aphasia and hemiplegia, though slight pyramidal damage indicated by unilateral or bilateral extensor plantar responses without gross weakness is frequently encountered.

Extrapyramidal disturbances so typical of the chronic stage may appear also in the acute. A Parkinsonian facies is often seen, but the muscles are usually hypotonic and rarely rigid. Rigidity, when present, is catatonic: true Parkinsonian rigidity is never present in the acute stage. Choreiform movements closely simulating Sydenham's chorea were not uncommon between 1916 and 1922, but now are hardly ever seen. The same is true of myoclonic muscular contractions, of which hiccup is perhaps a special form. These consist of shock-like muscular twitches varying in frequency from 8 or 10 to 80 contractions a minute and are especially common in the abdominal wall. They do not as a rule cause displacement of the limb segments. Sometimes muscles in different parts of the body may exhibit a synchronous myoclonus. Myoclonus may be associated with severe pain in the affected muscles. Hiccup may occur in the acute stage of encephalitis, with or without myoclonus elsewhere. Static and intention tremor are sometimes seen.

Spontaneous pains in the trunk and limbs occurred especially during the early years. Sensory loss is very uncommon, but the thalamic syndrome, with over-reaction to painful stimuli on one half of the body, has been observed.

The cerebellum and spinal cord are rarely involved, though muscular wasting and the clinical picture of transverse myelitis have occasionally been encountered, and a polyneuritic form of the disease is described.

The tendon reflexes are often diminished in the acute stage. Diminution of the abdominal reflexes is usually associated with other signs of a pyramidal lesion. There is usually no sphincter disturbance unless the patient is comatose, when retention or incontinence of urine and faeces may occur.

Signs of meningeal irritation, such as cervical rigidity and Kernig's sign, are very rare. The cerebro-spinal fluid is usually normal, though a slight excess of cells, almost always lymphocytes, is not uncommon. The protein and globulin are sometimes increased; the chloride content of the fluid is normal. There is no constant abnormality of the colloidal gold curve.

After passing through the acute stage the disease may become arrested or persist as a chronic and slowly progressive disorder. Complete arrest is rare, but even when it occurs the patient is likely to show some of the residual features about to be described, though in a non-progressive form. The chronic progressive form of the disease may follow an acute attack, or may develop insidiously, without being preceded by any recognizable acute symptoms. It was at first thought that the disabilities of function which followed encephalitis lethargica were not indications that the infection itself persisted. On pathological grounds it is now recognized as probable that in these cases the infection persists in a chronic form in some ways comparable with the tertiary stage of syphilis

SYMPTOMS OF THE CHRONIC STAGE

(1) *Parkinsonism.*

This is described in Chapter XII, pp. 511 and 517.

(2) *Sleep Disturbances.*

Lethargy or insomnia, or both, frequently outlast the acute attack, the form of disorder of sleep present in the acute attack usually persisting as a chronic symptom. In a small proportion of cases insomnia may first appear in the chronic stage. Some children exhibit a remarkable inversion of the normal sleep rhythm Towards evening they become excited and restless and spend the night talking and playing, falling asleep at dawn, and sleeping during the day for a normal number of hours. Narcolepsy is occasionally encountered as a sequel.

(3) *Mental Symptoms.*

Though gross mental disturbances have been reported in only 27 per cent. of cases, if less severe degrees of impairment of mental efficiency were included this figure would be much higher. In adults, in milder cases, nervousness, fatiguability, inability to concentrate, anxiety, and depression may persist for long periods. In some severe cases depression may lead to suicidal tendencies. Maniacal outbursts may occur. The Parkinsonian patient frequently exhibits a striking emotional impoverishment, gradually losing his former interests and spending his time in a state of complete affective indifference. Compulsive ideas may occur in patients who also exhibit compulsive movements (tics). In childhood the mental changes which may follow encephalitis are even more striking than in adults. Changes of emotional disposition are common in children, who may become restless and unstable and exhibit abnormalities of behaviour ranging from mere naughtiness to stealing, cruelty, acts of violence, and

F f

sexual offences, which may bring them into the hands of the police. Such children may be quite uncontrollable at home. Depression and suicidal tendencies and maniacal outbursts, though less common than the disorders already described, occasionally occur in childhood. Reduction of intelligence is not conspicuous, though permanent mental defect occasionally follows encephalitis lethargica, especially when the onset of the illness occurs during infancy.

(4) Ocular Abnormalities.

Gross ocular abnormalities, such as nystagmus, squint, and true diplopia, persist in only a small proportion of cases, but the patient often complains of dimness or mistiness of vision, which may be due to defective muscle-balance or weakness of accommodation. These symptoms are usually associated with slight inequality of the pupils and an impairment of pupillary reactions on accommodation, and less frequently to light. True Argyll Robertson pupil is occasionally encountered, but this is rare. Slight ptosis on one or both sides is frequent. Persistent paralysis of conjugate ocular movement is un-common, except that weakness of conjugate convergence is almost constantly present in encephalitic Parkinsonism and sometimes follows encephalitis apart from the Parkinsonian syndrome. Oculogyral spasm, one of the most striking ocular sequels of encephalitis, is described in the section on Parkinsonism.

(5) Involuntary Movements.

(i) *Choreiform movements* were at one time relatively common during the acute stage of the disease. They are rare during the chronic stage, but are occasionally observed.

(ii) *Bradykinesias.* This term has been applied to slow, regular, rhythmical movements of large amplitude, involving the limbs alone or the limbs and trunk. They are most frequently movements of torsion in the long axis, though these may be associated with movements of flexion or extension. In some instances these movements have been described as torsion spasm.

(iii) *Myoclonic movements.* Myoclonic movements were also at one time common during the acute stage and may in such cases persist, though usually in a less severe form, for many months.

(iv) *Tremor.* The commonest form of tremor occurring in chronic encephalitis is that associated with the Parkinsonian syndrome and described elsewhere. Less frequently the patient may exhibit tremor which is absent when the limbs are at rest, but occurs on voluntary movement or on attempting to maintain a posture. Such tremors may be localized to one limb or widespread.

(v) *Tics.* Repetitive movements resembling psychogenic tics are

occasionally seen in cases of chronic encephalitis, and are most common in association with disorders of respiration. Complex co-ordinated rhythmical movements, involving the jaw, lips, tongue, and palate, and also torticollis may occur

(6) *Respiratory Disturbances.*

Respiratory disturbances occurring during the chronic stage of encephalitis consist of disorders of the respiratory rate and rhythm, and respiratory tics.

The rate is most frequently increased, and the depth of respiration may be increased at the same time This tachypnœa may be continuous or paroxysmal The resulting increase in the ventilation of the lungs may lead to tetany Slowing of the respiratory rate is much less frequent and is usually compensated by considerable increase in depth of breathing

Disorders of respiratory rhythm consist of sighing, apnœic pauses, Cheyne-Stokes respiration, alternations of deep and shallow breathing, and breath-holding spells. Choreo-athetoid movements of the limbs and bizarre attitudes may accompany the last. Apnœa may be sufficiently severe to cause generalized convulsions The same patient may alternate between hyperpnœa, leading to tetany, and apnœa, leading to epileptiform attacks

Respiratory tics include yawning, sniffing, spasmodic cough, and spitting. Some patients complain of abnormal sensations referred to the respiratory tract, consisting of feelings of nasal or laryngeal *obstruction or thoracic discomfort.*

(7) *Metabolic and Endocrine Disorders.*

Metabolic and endocrine disorders, probably due to involvement of the hypothalamus, are rare Obesity, often associated with genital atrophy, is the commonest of these sequels. Polyuria associated with polydipsia may occur, though the urinary output does not often much exceed 100 oz. a day. Symptoms of hyperthyroidism with enlargement of the thyroid are also occasionally encountered. More frequently some of the former may be present without the latter, for example, exophthalmos, tachycardia, sweating, tremor, hyperglycaemia, and glycosuria Extreme cachexia is sometimes associated with the Parkinsonian syndrome. Excessive salivation and sebaceous secretion are also met with in Parkinsonism.

(8) *Epileptiform Convulsions.*

Epileptiform convulsions may follow encephalitis lethargica, as they may other infective conditions of the nervous system, but it is probable that this occurs only in patients who suffer from a predisposition to epilepsy.

of 25 per cent. solution being injected intramuscularly. Prolonged immersion in a hot bath is also of value.

Respiratory Disorders. Respiratory disorders are difficult to influence. Sedatives may be tried, and when tetany occurs it is necessary to combat the underlying alkalosis by means of ammonium chloride in 30-grain doses by the mouth every four hours.

Mental Disorders. The treatment of mental sequels of encephalitis in adults follows the usual lines. Mild cases can be treated at home or in hospitals, but more severe cases require certification. Children suffering from mental abnormality following encephalitis often require institutional treatment. Special arrangements for such children have been made in various parts of Great Britain, including the Post-encephalitic Unit, Northern Hospital, L.C.C., Winchmore Hill, Southmead Hospital, Bristol; Swinton House, Manchester; and the Darenth Colony of the L.C.C., Dartford. Those whose disorder takes the form mainly of criminal or immoral tendencies can now be dealt with as *moral defectives under the Mental Deficiency Act,* 1927, provided that the causative attack of encephalitis occurred before the age of 18 years. Moral defectives are defined by this Act as 'persons in whose case there exists mental defectiveness coupled with strongly vicious or criminal propensities and who require care, supervision, and control for the protection of others'. Treatment of such children in their own homes necessitates a regular life and sympathetic but firm handling, and should include training in handicrafts, physical exercises, and games. Sun baths and light baths are of value in improving both the physical and the mental condition.

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3 EPIDEMIC ENCEPHALITIS: JAPANESE TYPE B AND ST. LOUIS TYPE

Definition: These two varieties of epidemic encephalitis, the one occurring in Japan and the other in the United States of America have both been shown to be due to neurotropic viruses. These viruses are distinct because no cross-immunity exists between them, but the epidemiology and the pathological and clinical features of the two diseases are so similar that they can conveniently be considered together.

Aetiology.

The Japanese encephalitis type B is caused by a virus which was first transmitted to monkeys by Hayashi. Studies have been made by Kawamura and his fellow workers who transmitted the virus to mice and monkeys and proved that it was filterable (Inada, 1937 *a*, 1937 *b*). These workers also showed that it was immunologically distinct from the virus of the St. Louis epidemic. This was proved to be a filterable virus and transmitted to monkeys and mice by Muckenfuss, Armstrong, and McCordock (1933) and Webster and Fite (1935).

Epidemiology.

Eight epidemics of encephalitis occurred in Japan between 1871 and 1919, since when outbreaks have occurred every few years, and in 1935 there were 5,000 cases The St. Louis epidemic occurred in 1933 when there were over 1,000 cases in the neighbourhood during the late summer. There were smaller outbreaks in other cities in the

United States, including one in Toledo in 1934. The Japanese epidemics were also in the summer. In St. Louis relatively more cases occurred in the county than in the city. Multiple cases in the same family were not very common. The incubation period appeared usually to be between nine and fourteen days. There was a marked preponderance of susceptibility among the elderly and aged and a relatively small incidence upon children. Though mosquitoes have been considered as possible carriers both in the United States and in Japan, there is evidence that the disease is spread by human carriers and that the route of infection is the nose, from which the virus travels to the brain by the olfactory nerves.

Pathology.

The pathological picture in the two diseases is identical except that Japanese observers have described small patches of softening in the brain which were not observed in the American epidemics. All levels of the nervous system may be affected, and severe inflammation is always observed in the brain stem, the basal ganglia, and the white matter of the hemispheres. In distinction from encephalitis lethargica the inflammatory changes are much more diffuse in the Japanese and St. Louis forms, involving the basilar part of the pons, the entire width of the medulla, the cortex and white matter of the cerebellum, the basal ganglia, and also the cerebral cortex (Lowenberg and Zbinden, 1936). The brains show ganglion-cell degeneration, diffuse microglial and macroglial proliferation, and perivascular cuffing. Perivascular microglial nodes are common. Intranuclear inclusion bodies have been found in the cells of the tubular epithelium of the kidney.

Symptoms.

Several workers classify cases as (1) abortive, (2) mild, and (3) severe, including the fulminating cases. According to Hempelmann (1933) the onset of the disease is usually acute with high fever, 104° to 105°, headache, and stiffness of the neck and within a few hours many patients develop mental confusion and tremor of the lips, tongue, and hands. Rigidity may involve the upper limbs or the whole body. Drowsiness is common but the patient may be hyperexcitable. In severe cases coma develops early. The optic disks are usually normal and in distinction from encephalitis lethargica the pupils and their reactions are also usually normal. Cranial nerve palsies and gross palsies of the limbs are rare.

The cerebro-spinal fluid is usually clear, and under increased pressure. There is an excess of cells, usually between 50 and 250, predominantly lymphocytes. The globulin content is increased. The blood usually exhibits a moderate leucocytosis.

Diagnosis.

See diagnosis of encephalitis lethargica, p. 436.

Prognosis.

In the St. Louis epidemic the mortality rate was 20 per cent. In the Japanese epidemics it has been much higher, usually 50 to 60 per cent. In both the mortality rate increased after the age of 50. In favourable cases recovery is often rapid and complete. Many patients in the St. Louis epidemic had apparently completely recovered in from ten to fourteen days, but the disease sometimes runs a protracted course. A recent study by Bredeck and others (1938) of survivors of the 1933 St. Louis epidemic showed that 66 per cent. had made a complete recovery and only 6·3 per cent. were physically unfit for work. Severe Parkinsonism was so far quite rare.

Treatment.

Lumbar puncture is valuable and improvement often follows the first puncture, which can be repeated as necessary. No specific treatment is known and convalescent serum has apparently not been used. On general grounds it is not likely to be of value by the time a patient exhibits symptoms. Treatment therefore must be symptomatic and special attention will need to be directed to the feeding of the patient and the care of the bladder and bowels.

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4. AUSTRALIAN 'X' DISEASE

Definition: A form of acute encephalo-myelitis which has occurred in epidemic form in Australia. It is characterized by headache, lethargy, convulsions, and, in severe cases, coma, and has a high mortality rate. It appears to be due to a neurotropic virus which is transmissible to animals.

Aetiology.

The disease appeared in epidemic form in Australia in the late summer, between January and April, in 1917 and 1918. Fifty per cent of the patients were children under 5 years of age, but young adults were also affected. Males outnumbered females by more than 2 to 1. The disease appears to have been due to a filterable virus and was readily transmitted from man to animals, including monkeys and sheep, and from one animal to another. On clinical grounds it could be distinguished both from encephalitis lethargica and from poliomyelitis. The readiness with which it could be transmitted to animals also distinguishes it from encephalitis lethargica, and the fact that convalescent serum from cases of acute anterior poliomyelitis failed to neutralize the virus suggests that the two conditions are distinct. The evidence, therefore, points to Australian 'X' disease having been due to a specific and distinct neurotropic virus which Burnet (1934) and Perdrau (1936) have suggested may have been the virus of louping-ill of sheep.

Pathology.

Microscopical examination of the nervous system showed vascular engorgement and both diffuse and perivascular lymphocytic infiltration. In addition miliary foci of softening were observed in the cerebral cortex. Chromatolysis of ganglion cells, though present in affected parts of the brain, was not conspicuous. The pathological changes were most marked in the cerebral cortex, basal ganglia, dentate nuclei of the cerebellum, dorsal region of the pons and medulla, and the grey cornua of the spinal cord.

Symptoms.

The incubation period appeared to be between five and twelve days. The prodromal symptoms consisted of headache, lassitude, weakness, and pains in various parts of the body. These symptoms became more marked as the disease developed and were associated with vomiting, lethargy, delirium, and in severe cases coma. There was pyrexia, the temperature ranging from 101° to 105° F. Convulsions occurred in a large proportion of cases, and rigidity of the

limbs was common. The cranial nerves were rarely affected, except that dysphagia not uncommonly occurred. No lasting paralysis of the limbs was observed.

The cerebro-spinal fluid usually contained an excess of mononuclear cells, but no other marked abnormality, and cultures from the fluid proved negative.

Diagnosis.

The condition was distinguished from encephalitis lethargica by the infrequency of cranial nerve palsies, especially of pupillary abnormalities and other ocular symptoms, and from poliomyelitis by the absence of lasting paralysis of the atrophic type.

Prognosis.

The disease ran an acute self-limited course, fulminating cases proving fatal in twenty-four hours and the average duration of the illness being from seven to twelve days. The mortality rate was high —70 per cent.—but those who recovered usually did so completely, only three suffering from paralysis and two from mental disorder as immediate sequels. Whether later sequels corresponding to a chronic stage of the disease have occurred, as in the case of encephalitis lethargica, is unknown.

Treatment.

As in the case of other forms of acute encephalo-myelitis, repeated lumbar puncture should be carried out, the treatment otherwise being symptomatic.

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5. POLIOMYELITIS

Synonyms: Infantile paralysis; Heine-Medin's disease.

Definition: An acute infective disease due to a virus with a predilection for the cells of the anterior horns of the grey matter of the spinal cord, destruction of which causes muscular atrophy and paralysis.

Pathology.

In the acute stage naked-eye examination yields evidence of a general reaction to the infection in parenchymatous degeneration of the liver and kidneys and a general enlargement of the lymphoid tissue of the body, including the lymphatic glands of the alimentary canal. The spinal cord is congested, soft, and oedematous, and minute haemorrhages may be visible in the grey matter.

Histologically the changes in the nervous system are usually most marked in the grey matter of the spinal cord and medulla. The basal ganglia and cerebral cortex are little affected. In the cord the changes consist of degeneration of the anterior horn cells and an inflammatory reaction with small haemorrhages in the grey matter. The ganglion cells of the anterior horns show changes of all degrees of severity from slight chromatolysis to complete destruction with neuronophagia. The inflammatory reaction consists of perivascular cuffing, mainly with lymphocytes but with a smaller number of polymorphonuclear cells, and a diffuse infiltration of the grey matter, with similar cells and cells of neuroglial origin (Fig. 48). The white matter of the cord shows some perivascular infiltration. The meninges share in the inflammatory reaction, exhibiting infiltration with lymphocytes and endothelial cells.

Cortical lesions are similar but are more focal, and inflammatory changes have also been observed in the spinal posterior roots and in the peripheral nerves. In rare cases the brunt of the infection falls upon the brain-stem. Focal necroses are found in the liver, and an inflammatory hyperplasia in the lymphoid tissue.

Recovery from the acute stage is attended by restoration to normal of ganglion cells which have not been too severely damaged. Others disappear completely, and sections therefore show a paucity of cells in the anterior horns in the affected regions with secondary degeneration in the corresponding anterior roots and peripheral nerves. The muscles supplied by these segments show varying degrees of atrophy with a relative increase of the connective tissue and fat.

Aetiology.

Our knowledge of the causative organism of poliomyelitis dates from the observation of Landsteiner and Popper in 1909, that the disease could be transmitted to monkeys, and it has since been shown to belong to the group of filterable viruses and to possess the general characteristics of members of this group. The virus can be obtained from the nervous system of fatal cases, especially from the spinal cord, but also, as Flexner, Lewis, and others have shown, from the nasopharyngeal mucous membranes of patients in the acute stage, of healthy contacts, and of convalescents. Monkeys can be

successfully inoculated by direct intracerebral injection or by injection subcutaneously, intraperitoneally, into the lymph glands, or into a nerve-trunk, but it is now recognized that the disease is spread by droplet infection and that the normal route of infection is through the nose. Having reached the naso-pharynx the virus invades the nervous system through the olfactory hairs and thence by the
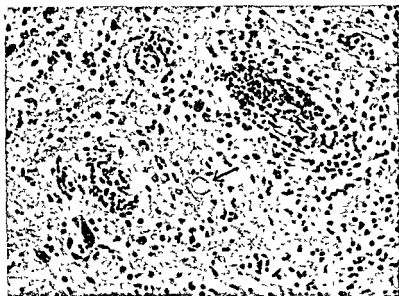
FIG. 48. Poliomyelitis. Anterior horn showing inflammatory infiltration and advanced chromatolysis of neurone (arrow) H.E. × 215.

olfactory bulbs and tracts. Fairbrother and Hurst's work has shown that the virus travels readily along the axis cylinders both in the peripheral nerves and in the central nervous system and no doubt it is by the long descending tracts that, having reached the brain, it descends to the anterior horn cells of the spinal cord. These it invades, the inflammatory changes in the nervous tissues and meninges being purely reactive. It is unlikely that the blood or the cerebro-spinal fluid plays an important part in the dissemination of the virus, but it is possible that exceptionally the pharynx or tonsils may be the portal of entry (Scott-Brown, 1931) or the raw tonsillar bed after tonsillectomy (Aycock and Luther, 1929).

Epidemiology.

In Great Britain poliomyelitis occurs for the most part sporadically, but small epidemics occasionally break out. The United States is

subject from time to time to severe epidemics, and Wickman has studied epidemics in Norway and Sweden. This worker found ample evidence that the transmission of the disease could often be traced to an apparently healthy individual who had been in contact with a paralytic case but never himself developed the disease. Such healthy carriers and abortive cases in which recovery occurs before the *paralytic stage is reached greatly outnumber the paralytic cases and* are probably mainly responsible for the spread of the infection, though there is evidence that the disease can be acquired from a paralytic case. It is believed that in a community such as a boarding-school a carrier epidemic precedes the appearance of overt cases, so that by the time frankly paralytic cases appear the whole population may already have been exposed to the infection. There is little to indicate that the disease is spread by fomites, insects, or other external agencies, though a small epidemic has been traced to a milk *supply and the virus has been demonstrated in the faeces of patients.*

The seasonal incidence in the late summer and early autumn is unexplained. Infants under the age of 1 year are rarely attacked. Most sufferers are between the ages of 2 and 4. After the age of 5 susceptibility rapidly diminishes, and after the age of 25 the disease is very rare. Males suffer somewhat more frequently than females. The incubation period appears to be usually about twelve days.

Symptoms.

There are four possible ways in which a person may react to infection by the virus of poliomyelitis. (1) There is evidence (Wells, 1932) that exposure to the virus leads in a large majority of cases to development of immunity without any symptoms of illness. This may be termed sub-clinical infection. (2) Most workers believe that there are patients in whom the symptoms are never more than those of a mild general infection without involvement of the nervous system. The most recent knowledge of neurotropic viruses perhaps renders this doubtful, but such cases, if they occur, may be termed abortive cases. (3) A majority of patients, in some epidemics as many as 75 per cent., develop general symptoms and at this stage exhibit an excess of cells in the cerebro-spinal fluid yet never develop paralysis. Evidently, though the nervous system is invaded, the anterior horn cells are not attacked. The infection is overcome in the pre-paralytic stage and these are called pre-paralytic cases. (4) Only in a minority does the infection run its full course and cause paralysis.

(1) Patients with sub-clinical infections exhibit no symptoms. (2) Symptoms of patients of the abortive type are indistinguishable from those of any other general infection unless the virus can be

demonstrated in the naso-pharynx. There remain to be considered the symptoms of (3) the pre-paralytic stage and (4) the stage of paralysis.

The Pre-paralytic Stage.

In this stage two phases can often be recognized. The first symptoms of infection are fever, malaise, headache, drowsiness or insomnia, sweating, flushing, faucial congestion, and often gastro-intestinal disturbances such as anorexia, vomiting, and diarrhoea Faber (1933) interprets these symptoms as due not to a general infection but to invasion of the hypothalamus by the virus. This phase, which lasts one or two days, is sometimes followed by temporary improvement with remission of fever for forty-eight hours, or it may merge into the second phase in which headache is more severe and associated with pain in the back and limbs, together with hyperaesthesia often of both the superficial and deep tissues

Delirium may occur. The child is often tremulous, and cervical rigidity and Kernig's sign may be observed. In the absence of such marked signs of meningeal irritation the 'spinal sign' is of diagnostic value. In adults, infants, and children too ill to be taken from bed this is elicited by means of passive flexion of the spine when the patient is lying on his side, resistance being encountered on account of pain in the back. In children who are not too ill the sign is best elicited by taking the child from the bed, supporting it in a sitting position, and asking it to try to kiss its knee. Flexion of the spine, even when assisted by passive movement, is prevented by pain. Convulsions may occur in infants in either of the first two phases.

The Cerebro-spinal Fluid.

In the second phase the cerebro-spinal fluid shows changes which are the outcome of meningeal irritation. The pressure is increased and there is an excess of cells, usually 50 to 250 per c.mm During the first few days both polymorphonuclear cells and lymphocytes are present, but after the first week lymphocytes alone are found. The protein and globulin show a moderate increase, but the glucose and chloride content of the fluid is normal.

The Paralytic Stage.

The Spinal Form. The onset of paralysis follows rapidly upon the pre-paralytic stage, and is attended by considerable pain in the limbs and tenderness of the muscles on pressure. The paralysis may be widespread or localized. In severe cases the muscles of the neck, trunk, and all four limbs may be powerless, except for a feeble movement here and there. When the paralysis is less extensive its

asymmetry and patchy character are conspicuous features, and some muscles may be severely affected on one side of the body and escape injury on the other. Usually the maximum of damage is done within the first twenty-four hours, but sometimes the paralysis is progressive. In the ascending form it gradually spreads upwards from the legs, and a descending form is described. The lower limbs are more often affected than the upper. In the former the muscles below the knee suffer most, especially the peronei and the anterior tibial group. In the latter the small muscles of the hands are frequently involved.

Fortunately it is the rule that only a proportion of the muscles affected at the outset remain permanently paralysed. Intoxication produces temporary loss of function in many anterior horn cells which ultimately recover. Improvement usually begins at the end of the first week after onset of the paralysis. In common with other causes of lower motor neurone paralysis, poliomyelitis leads to wasting of, and loss of cutaneous and tendon reflexes carried out by, the affected muscles, though the tendon reflexes may be exaggerated for a brief period at the onset. Complete paralysis of the muscles around a joint may permit subluxation to occur. When opposing muscle groups are unequally affected, contractures are apt to occur in the stronger muscles, causing limitation of movement at the joint. In the upper limb this most often happens in the adductors of the shoulder after paralysis of the deltoid; in the lower limb, in the calf muscles, after paralysis of the peronei and anterior tibial group. Talipes equino-varus results from contracture of the calf. Asymmetrical palsy of the spinal muscles causes scoliosis. The affected limbs are blue and cold and may be the site of oedema or chilblains. Bone growth is retarded in the paralysed limbs, and the bones show rarefaction radiographically.

Rarely the inflammation extends to the white matter of the lateral columns of the cord. Involvement of the spino-thalamic tracts causes impaired appreciation of pain, heat, and cold, and damage to the pyramidal tracts leads to spastic paralysis. Such an extension in the cervical enlargement produces spastic paraplegia associated with muscular wasting of the upper limbs. Except in such cases sphincter disturbance is very rare and sensory loss is absent.

Brain-stem Form. In a small percentage of cases the brunt of the infection falls upon the brain-stem, leading to facial, pharyngeal, lingual, or very rarely ocular paralysis. Tremor and nystagmus may be present.

Diagnosis.

Diagnosis is rarely possible in the stage of constitutional disturbance, except in an epidemic. Even then suspicion cannot be

confirmed until changes in the cerebro-spinal fluid indicate that the nervous system is invaded. At this stage in sporadic cases the disease has to be distinguished from other causes of meningeal irritation. In the acute pyogenic forms of meningitis the glucose content of the spinal fluid is reduced, and the cells are exclusively polymorphonuclear. Mumps meningitis which is also associated with a lymphocytic pleocytosis in the spinal fluid is not likely to cause confusion, since the parotitis is usually evident. Tuberculous meningitis may be difficult to distinguish. In this condition the onset is usually more gradual and the child is pale rather than flushed as in poliomyelitis. The diagnosis, however, rests upon the examination of the spinal fluid, which in both may contain an excess of cells, both polymorphonuclear and lymphocytes, and an excess of protein. In poliomyelitis the chloride content of the fluid is normal; in tuberculous meningitis it is diminished and may even be as low as 0·5 per cent. Tubercle bacilli if present are, of course, conclusive.

The spinal form of the disease in the paralytic stage is usually easy of diagnosis. When the pain and tenderness are severe it may be confused with acute rheumatism, syphilitic epiphysitis, and acute osteomyelitis. In these, however, the tenderness is more localized than in poliomyelitis and in the first two is related to the joint; in the last the lesion is often near a joint. Moreover, in none of these are the tendon reflexes lost as in poliomyelitis. The Wassermann reaction is usually positive in cases of the syphilitic lesion.

In adults poliomyelitis may need to be distinguished from acute transverse myelitis, but in this condition flaccid paralysis of the legs is associated with extensor plantar reflexes, sensory loss, and loss of sphincter control.

When the patient is seen years after the acute attack the presence of muscular wasting may suggest progressive muscular atrophy, syringomyelia, or myopathy. The fact that the wasting is not progressive, however, excludes all these alternatives. The absence of fibrillation also helps to distinguish it from the first named, and the absence of sensory loss from the second, while the wasting is usually too patchy and asymmetrical to simulate myopathy very closely.

The bulbar form must be distinguished from other forms of encephalitis. In encephalitis complicating the exanthemata and vaccination the primary cause is usually obvious. In encephalitis lethargica the onset is usually less acute, signs of meningeal irritation are absent, and pupillary disturbances are almost constant.

Prognosis.

The mortality varies in different epidemics and may be as high as 25 per cent. The mortality rate is highest in the first year of life

and in those who are attacked after the fifth year. The cause of
death is usually respiratory paralysis due to direct involvement
of the respiratory centres in the bulbar form or to paralysis of
the intercostals and diaphragm, which is most liable to occur in the
ascending form of the disease. The patient may survive the acute
stage only to succumb later to broncho-pneumonia.

When the progress of the paralysis has ceased it is safe to predict
that considerable recovery will occur. Favourable indications are
the presence of voluntary movement, of reflex responsiveness, and
of a reaction to faradism which persists three weeks after the onset
of the paralysis. Improvement once begun may be expected to
continue for at least a year and in some cases for even longer. The
nature and extent of the remaining disability will, of course, depend
upon the distribution of the residual paralysis. Second attacks,
though very rare, are well authenticated.

Progressive muscular atrophy is a rare sequel of acute anterior
poliomyelitis, which it may follow after many years, the progressive
wasting usually beginning in the region originally affected.

Treatment.

General Management.

During the acute stage aperients will be needed as patients are
usually constipated, and plenty of fluid should be given. Lumbar
puncture may be needed for diagnostic purposes and may help to
relieve headache and backache. Aspirin in doses of 5 to 10 grains and
sedatives, such as phenobarbital or bromide and chloral, will be
required for the relief of pain and restlessness. Hypertonic saline
baths diminish the hyperaesthesia. Gentle passive movements are
the only form of physical treatment which is permissible at this
stage. When the respiratory muscles are involved the foot of the bed
should be raised 2 to 3 feet and atropin given. Artificial respiration
by means of a Drinker or Bragg-Paul respirator may be needed to
tide the patient over a period of respiratory paralysis, but it must be
remembered that improvement in the respiratory muscles often does
not occur.

Serotherapy.

The objects of treatment are to combat the infection and to pro-
mote recovery from, and minimize the effects of, the muscular
paralysis. There is ample experimental evidence that the blood-
serum of convalescent individuals contains antibodies capable of
neutralizing the virus, and this has led to the use of such serum in
treatment, but the results have been disappointing. As soon as the
virus has entered the nervous system it is beyond the reach of

antibodies. Schultz and Gebhardt (1933, 1934, and 1935) and Flexner (1938) have shown that a potent neutralizing serum was ineffective if given more than twenty-four hours after nasal instillation of the virus in monkeys. This is borne out by clinical experience, for though good results have been claimed for convalescent serum in treatment by some workers the best controlled observations, such as Park's (1932) on nearly 1,000 cases, showed no significant difference between treated and untreated patients.

Those who advocate serum agree that it should be given in the pre-paralytic stage. Macnamara and Morgan (1932) advocate a dose up to 30 c.c. intrathecally and a sufficient dose intravenously to bring the total up to 50 c.c.

Treatment of the Paralysis.

For purposes of treatment the course of the disease after the onset of paralysis is divided into (1) An acute stage, during which pain *and tenderness of the muscles persist.* This usually lasts for three or four weeks. (2) A convalescent stage during which improvement in muscular power continues. This may last from six months to two years. (3) A chronic stage in those left with permanent paralysis after the maximum recovery has occurred.

The principal object in the treatment of the muscular paralysis in the acute stage is to prevent stretching of the paralysed muscles and contracture of their antagonists. If great care is not taken over this, damage may be done in a few days which it will take months to repair. The patient should be nursed on a firm bed and the limbs kept in the positions in which the paralysed muscles are relaxed by means of sandbags, improvised splints, or plaster beds. Special care should be taken to keep the shoulder abducted to a right angle when the deltoid is paralysed. To do this the arm may be fixed to the head of the bed with a sling. In the lower limbs outward rotation of the limbs, flexion of the hip and knee, and dropping and inversion of the foot must be prevented. A small but important muscle is the opponens of the thumb which should not be allowed to become stretched.

During the stage of convalescence prolonged rest in bed will be necessary in severe cases, the limbs being kept in position by means of a spinal frame or by a double Thomas splint with foot pieces and malleable arm pieces, and in less severe cases by appropriate splints applied to the individual limbs. Except when the trunk muscles are severely paralysed the patient may usually be allowed to stand for a few minutes daily after some months, but paralysis of the spinal muscles requires prolonged recumbency even up to two and a half years if severe spinal deformity is to be prevented. During conva-

lescence active exercises are of great importance. They may need to be assisted or carried out in baths. Passive movements and massage are also necessary, but the value of electrical treatment is doubtful. Adequate instrumental support for the spine and limbs may be required and falls within the province of the orthopaedic surgeon. In the later stages contractures and deformities may require tenotomy or other surgical treatment, but these may often be avoided by adequate care during the acute stage.

In the chronic stage when oedema, cyanosis, and chilblains are troublesome in the feet, lumbar sympathectomy may be helpful in improving the circulation.

Prophylaxis.

Since the naso-pharyngeal secretions, the urine, and the faeces of the patient may contain the virus the usual precautions taken in nursing cases of infectious disease should be adopted. It is not easy to say how long the patient remains infectious, but he should be isolated from other children for at least six weeks. The infectiousness of the paralytic case, however, is not very great, as case to case infection is rare.

During an epidemic it is desirable as a rule that residential schools should not be closed. For reasons given in the section on epidemiology it is unlikely that closure of a school will modify the spread of the disease among those already exposed to it, and there is a risk that this course will tend to disseminate the infection among younger and therefore more susceptible children. Children in an affected household should be isolated from other children for three weeks after the isolation of the patient.

The prophylactic value of immune serum has been established experimentally and it may justifiably be used during an epidemic especially for the protection of child contacts. A dose of from 10 to 20 c.c. of a convalescent serum may be injected subcutaneously or intramuscularly and as the serum of many normal adults possesses the power of neutralizing the poliomyelitis virus the pooled serum of two or more adults may be used if convalescent serum is not available. Fifty c.c. of citrated whole blood may also be used. Since it is believed that human serum and blood afford protection for only about three weeks the injection may need to be repeated in an epidemic. Immune horse serum may be used instead in a dose of 10 c.c. intramuscularly.

Active immunization encounters the difficulty that viruses unlike bacteria do not evoke immunity when killed. The dangers of immunization with a living virus have not yet been overcome.

Attempts have been made to block the route of ingress of the virus

by spraying the nose with various protective substances. A 1 per cent. solution of zinc sulphate though effective in monkeys, proved ineffective in man. A solution consisting of 0·5 per cent. of picric acid and 0·5 per cent. of sodium aluminium sulphate in 0·85 per cent. saline has also been employed, each nostril being sprayed every other day for a week and subsequently once a week during the epidemic. The value of this is not yet established and it must be borne in mind that substances powerful enough to protect against the virus may not be free from the risk of causing permanent damage to the nasal mucous membrane.

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6. RABIES

Synonym: Hydrophobia.

Definition: An infection of the nervous system due to a filterable
neurotropic virus communicated to man by the bite of an infected
animal. The resulting encephalitis, which is almost always fatal, is
distinguished by the characteristic pharyngeal spasm evoked by the
attempt to drink.

Aetiology.

Rabies is due to a filterable virus which possesses a predilection for
the nervous system. It is communicated to man by the bite of an
infected animal which carries the virus in its saliva. Most cases of
human infection are due to dog bites, though bites of jackals, cats,
and wolves are occasionally responsible. The bites of rabid horses
and cattle hardly ever communicate the disease. An epidemic in
Trinidad has been attributed to vampire bats which have been
believed to carry the infection from cattle to man. The virus of
rabies has been isolated from a fatal case occurring in a human
epidemic of encephalitis in Japan. The risk of infection is influenced
by the severity of the bite and is much diminished when the indi-
vidual is bitten through clothes, which to some extent free the
animal's teeth from saliva. The virus, having entered the body, is
transmitted only along the nerve-trunks, moving in both directions.

Pathology.

The pathological changes in the nervous system exhibit the general
characteristics associated with infection with a neurotropic virus.
Severe degenerative changes are found in the ganglion cells of the
cerebro-spinal and sympathetic ganglia. The small vessels show
narrowing of the lumen and enlargement of the endothelial cells,
with marked perivascular round-cell infiltration. The ganglion-cell
degeneration is more diffuse than the inflammatory reaction, and the
ganglion cells of the cortex may be extensively affected. There is
considerable reaction of oligodendroglia and microglia, and collec-

tions of inflammatory and glial cells are known as Babes' nodes. The Negri body is of diagnostic importance. It is an acidophil inclusion body contained within the cytoplasm or protoplasmic processes of the ganglion cells. Negri bodies are most constantly present in the ganglion cells of the hippocampus major, but may also be found in the pyramidal cells of the cortex, the Purkinje cells of the cerebellum, and the ganglion cells elsewhere. Negri bodies are not constantly present in human rabies nor in the experimental infection of animals with the virus fixe.

The pathological picture in the so-called 'neuro-paralytic accidents' occurring during the prophylactic treatment of rabies may be different (see p. 457).

Symptoms.

Rabies in Animals.

The first symptoms of rabies in the dog are a change in behaviour associated with perversion of appetite. The animal will gnaw and swallow paper, sticks, earth, and other unusual substances. This stage is followed by excitement, in which it will snap at and bite other animals. There is a flow of saliva from the mouth, and the bark often becomes high-pitched. After one or two days paralysis develops, beginning first in the hinder extremities and spreading to the forelimbs and jaw. Muscular spasms may occur affecting the whole body. Emaciation is marked and death is almost invariable.

In other animals, especially rodents and herbivora, the stage of excitement does not occur and the symptoms are paralytic from the beginning, and this paralytic form of the disease occurs in a small proportion of dogs.

Rabies in Man.

The incubation period in man depends upon the distance of the infected lesion from the central nervous system. When the bite is on the head it is about 27 days, when on the arm 32 days, when on the leg 64 days, but these periods are liable to wide variations. During the incubation period there are no symptoms. Local pain in the bitten limb is often the first symptom to appear. The first general symptoms are depression, often associated with apprehension, and disturbed sleep. The next symptom is pharyngeal spasm brought on by the attempt to drink and rapidly extending to involve both the ordinary and the accessory muscles of respiration, and later all the muscles of the body, often producing opisthotonos. When this stage is at its height not only the attempt to drink but the sound and even the thought of water will bring on the spasm, which may also be excited by other external stimuli. Salivation is excessive, and vomit-

ing is common. A horror of water develops and hallucinations may appear. Even so, the human patient does not as a rule exhibit the impulse to *bite characteristic of the rabid dog*. *Later the symptoms of excitement and the spasm diminish* and may give place to a terminal paralysis. Fever is usually present, and a terminal hyperpyrexia may occur. Death may take place during the spasmodic stage from respiratory or cardiac failure, or the patient may die in coma in the stage of paralysis.

Rarely the spasms and mental excitement are absent and the *symptoms are paralytic from the beginning, as is the case in certain* species of animal. An epidemic of paralytic rabies recently occurred in Trinidad. In such cases the clinical picture is that of an ascending paralysis beginning in the lower limbs and associated with loss of sphincter control. The upper limbs may or may not be affected and sensory loss is inconstant. Finally bulbar paralysis leads to dysphagia and death occurs from paralysis of the respiratory muscles.

Diagnosis.

The diagnosis of typical hydrophobia is usually easy on account of the history of the bite and the presence of the distinctive pharyngeal spasm. The condition must be distinguished from tetanus, the incubation period of which is shorter. The symptoms of tetanus unmodified by the injection of serum usually begin within fourteen days of the injury and almost invariably within three weeks. In tetanus trismus is an early symptom and pharyngeal spasm is usually absent.

Hysteria may simulate hydrophobia in a patient who has been bitten by a dog which is supposed to be rabid. In hysteria, however, true pharyngeal spasm does not occur and the condition is amenable to sedatives combined with suggestion.

The paralytic form of rabies should offer no difficulty in diagnosis when there is a history of a bite, but in cases such as those in Trinidad, when the mode of infection is obscure, the diagnosis may only be established by means of animal experiments.

Prognosis.

The risk of contracting rabies is estimated at about 5 per cent. of individuals bitten by animals supposed to be rabid. Adequate prophylactic treatment reduces this incidence to about 1·5 per cent. Those who develop rabies almost invariably die, though recovery has occasionally been reported. The prospects of recovery from the 'neuro-paralytic accidents' of rabies treatment are good.

Prophylaxis and Treatment.

The prophylactic treatment of rabies introduced by Pasteur is still carried out, though it has been modified in various details. It

consists of successive doses of a vaccine derived from animals which have been infected with the virus fixe. The vaccine may consist of living or dead virus from the cord or brain of infected animals and may be given alone or combined with antiserum. Its administration should be begun as early as possible after the bite. The long incubation period of rabies permits the development of an acquired immunity after infection. The prophylactic vaccine treatment of rabies is thus analogous to the vaccination of individuals after exposure to small-pox. The bite itself should be treated with antiseptics, though cauterization has little influence in preventing the development of the disease. When rabies has developed, treatment is purely symptomatic, its principal object being to diminish the spasms. Curare has been used to achieve this end by causing muscular paralysis, but is uncertain in its action owing to the absence of a standardized preparation. The dose is 1/16th to $\frac{1}{2}$ grain repeated every half-hour until general muscular paralysis develops, and renewed when necessary. A combination of chloral and morphine may be tried. The paralytic form of the disease will require the usual treatment of paraplegia. Artificial respiration with Drinker's or a Bragg-Paul respirator may be needed.

7. THE NERVOUS COMPLICATIONS OF ANTIRABIC TREATMENT

The cause of the nervous complications which are a rare sequel of antirabic treatment is obscure. Their incidence varies from about 1 in 1,000 to 1 in 4,000 patients treated, and is lowest when the carbolized vaccine is used. It has been suggested (1) that the nervous symptoms are due to a modification of the original infection with rabies by the subsequent inoculation, (2) that they are the direct result of the inoculation itself, being caused either by the virus or by a toxic component of the nervous substance introduced with it; (3) that they are due to some other virus or toxin stimulated into activity by the inoculation. It is possible that the cause is not always the same.

Pathologically in some cases the only changes described have been degeneration of the ganglion cells with perivascular congestion. In one case, however, perivascular round-cell infiltration with demyelination and axis cylinder destruction were present.

Three clinical forms of the so-called 'neuro-paralytic accident' have been described. (1) An ascending paralysis similar to the paralytic form of rabies; (2) transverse myelitis in the dorsal and lumbar regions, and (3) multiple neuritis involving various peripheral nerves, most frequently the facial. These varieties occur with

approximately equal frequency and the prognosis is good as to life except in the first group in which the death-rate is 30 per cent. Treatment is symptomatic.

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8. ACUTE ASEPTIC MENINGITIS AND ACUTE LYMPHOCYTIC CHORIO-MENINGITIS

Definition: Acute aseptic meningitis may be defined as an acute infection of the meninges occurring in the absence of any evident focal or general cause of infection, characterized by the rapid onset of symptoms of meningeal irritation, a pleocytosis in the cerebrospinal fluid and the absence of bacteria from films and cultures of the fluid, and running a benign course. In a proportion of cases, 28 per cent. in Baird and Rivers (1938) series, this clinical picture has been caused by a filterable virus, that of acute lymphocytic chorio-meningitis. In the remainder the cause is unknown. MacCallum, Findlay, and Scott (1939), however, have isolated a virus allied to but distinct from that of acute lymphocytic chorio-meningitis, and it seems likely that acute aseptic meningitis may be produced by several viruses. Since the clinical picture appears

to be similar in all cases the description given in this section is of acute lymphocytic chorio-meningitis about which most is known.

Synonyms: Acute benign lymphocytic meningitis, epidemic serous meningitis.

Aetiology.

The disorder occurs sporadically and also in small epidemics Children are usually affected, but it may occur in adults also The work of Armstrong and Lillie (1934), Findlay, Alcock, and Stern (1936), and others has shown that it is caused by a filterable virus, which has been recovered from the cerebro-spinal fluid of patients and transmitted to mice and monkeys. Mice are subject to the disease in the wild state and may be the source of the human disease, which has been encountered in Europe, North America, New Zealand, and Malaya.

Pathology.

Animals infected experimentally show intense lymphocytic infiltration of the leptomeninges, the ependyma of the ventricles and the choroid plexuses Viets and Warren (1937) report similar changes in a fatal case together with degeneration of the ganglion cells of the brain which in the mid-brain showed cytoplasmic inclusion bodies. Perivascular infiltration with round cells was seen in both the brain and the spinal cord.

Symptoms.

The onset is acute, and symptoms of meningeal irritation usually develop rapidly but there may be prodromal manifestations of a general infection. The symptoms resemble those of acute pyogenic meningitis. Papilloedema may occur, and squint and nystagmus are common. Apart from the occasional occurrence of facial paralysis, the other cranial nerves are normal Paraplegia and retention of urine have been described but symptoms of invasion of the substance of the nervous system are rare. There is usually high fever at the onset, and as a rule the temperature falls by lysis in about a week.

The cerebro-spinal fluid is under increased pressure and may be clear, turbid, or, exceptionally, purulent The albumin and globulin are increased and a 'cobweb clot' has occurred in some cases. There is an excess of cells ranging from 50 to 1,500 per c.mm.; about half show over 1,000 at some stage. These may be mainly mononuclear from the onset, but in a minority of cases polymorphonuclear cells predominate at the beginning, giving place to mononuclear cells in the course of the first week. The chloride and sugar content

of the fluid is usually little, if at all, depressed. The pleocytosis in the cerebro-spinal fluid is often remarkably persistent, and in some of my own cases a considerable excess of mononuclear cells has been present for many weeks after the disappearance of symptoms, when the patient has apparently been in normal health.

Diagnosis.

For the diagnosis of meningitis see p. 351.

Acute lymphocytic chorio-meningitis is most likely to be confused with tuberculous meningitis, and since the absence of tubercle bacilli from the cerebro-spinal fluid cannot be held to exclude the latter, the two conditions may be indistinguishable until the recovery of the patient settles the diagnosis in favour of the benign disorder. The acuteness of the onset of symptoms in acute lymphocytic chorio-meningitis may help to distinguish this condition from the tuberculous form. Mumps meningitis is very similar, but will usually be distinguished by the presence of parotitis or orchitis.

Prognosis.

The prognosis is good and complete recovery is the rule. Paraplegia, however, may be permanent and diffuse arachnoiditis has been described as a sequel.

Treatment.

The usual general treatment of meningitis should be carried out, including drainage of the cerebro-spinal fluid by lumbar puncture, which should be performed as often as is necessary for the relief of headache.

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9. NERVOUS COMPLICATIONS OF MUMPS

Aetiology.

The experimental work of Gordon lends support to the view that mumps is due to infection with a filterable virus which possesses potential neurotropic propensities. Gordon was able to produce meningitis in monkeys by the intracerebral injection of a filtrate of the saliva of patients suffering from mumps. Since the commonest nervous complication of mumps is meningitis, it seems probable that this is due to an infection of the meninges with the mumps virus. The much rarer lesions of the substance of the nervous system may be due to a spread of this infection from the meninges to the neural axis, or may possibly be the result of an acute encephalo-myelitis similar to that complicating other specific fevers.

Pathology.

Little is known about the pathology of the nervous complications of mumps. After experimental infection of monkeys, hyperaemia of the brain and meninges, with lymphocytic infiltration of the latter, is found. In one case of encephalitis complicating mumps Bien observed in addition to leptomeningitis an area of demyelination in the corona radiata.

Symptoms.

Nervous symptoms may occur at the onset or during the first stage of the disease, but usually develop somewhat later, in the adult male immediately before the appearance of orchitis. They may occur without parotitis but with orchitis. The symptoms are usually those of an acute meningitis (see p. 348), but in rare cases aphasia and hemiplegia have been described. Optic neuritis and optic atrophy are rare complications. Deafness, either unilateral or bilateral, is commoner.

A small number of cases of polyneuritis occurring in association with mumps have been recorded, usually developing two or three weeks after the onset of the primary symptoms. In all the reported cases there has been a flaccid paralysis of all four limbs, and in some cases cranial nerve paralyses have occurred, most frequently facial paralysis. Localized neuritis is also sometimes encountered, for example unilateral facial paralysis.

The cerebro-spinal fluid usually exhibits a marked lymphocytosis in cases of meningitis. Monod first pointed out that this is frequently present in mumps in the absence of any meningeal symptoms, and it may also occur in contacts who never develop the disease.

Diagnosis.

The parotitis usually renders the diagnosis easy. In cases of meningitis associated with lymphocytosis of the cerebro-spinal fluid for which no cause can be found, inquiry should always be made whether symptoms of parotitis or orchitis have been present, as this may not have been mentioned spontaneously.

Prognosis.

Recovery from mumps meningitis is the rule, but the condition is occasionally fatal. Polyneuritis also usually recovers, though slowly, and recovery may be incomplete.

Treatment.

Mumps meningitis is best treated by a daily lumbar puncture during the acute stage and analgesics will be required. In severe cases convalescent serum should be given, if this is obtainable, in doses of 10 c.c., intramuscularly or intravenously, repeated as required For the treatment of polyneuritis see p. 707.

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10. HERPES ZOSTER

Synonym: Shingles.

Definition: An acute infection involving primarily the first sensory neurone and the corresponding area of skin.

Pathology.

The pathological changes in the nervous system are those of an acute inflammation at some point in the course of the first sensory neurone. The posterior root ganglia and the corresponding sensory ganglia of the cranial nerves are the commonest sites of the lesion, but the posterior horn of the grey matter of the spinal cord, the posterior root, and the peripheral nerves may also be involved. One or more successive metameric segments may be affected, but it is very rare for the lesion to be bilateral. The microscopical changes in the acute stage consist of haemorrhages and infiltration with mononuclear and occasional polymorphonuclear leucocytes, especially in the form of perivascular cuffs, and degenerative changes in the nerve-cells. Fibrosis and secondary degeneration follow in severe cases. Inflammatory changes are present in the neighbouring lepto-meninges. In a fatal case of zoster meningo-encephalitis chromatolysis of ganglion cells and perivascular infiltration were found at all levels of the nervous system up to the cerebral cortex (Biggart and Fisher, 1938). The cutaneous lesions show inflammatory infiltration of the epidermis and dermis, with vesicle formation produced by serous exudation beneath the stratum corneum. Acidophil nuclear inclusion bodies have been described in the cells of the vesicle epithelium.

Aetiology.

These pathological changes are clearly infective, and the infective character of zoster is borne out by numerous facts. It often occurs in epidemics with a seasonal incidence, most cases occurring in the early summer and late autumn. The contagiousness of the infection is well established. It is closely related to varicella, and there is reason to believe that in the majority of cases, if not in all, zoster and varicella are due to the same organism. Either may give rise to the other in contacts, though varicella follows exposure to zoster much more frequently than the reverse. The zoster-varicella virus is entirely distinct from that responsible for simple or febrile herpes.

Zoster may occur without any evident predisposing cause, or as a complication of some other disease or toxic state, especially when this causes damage to the first sensory neurone. These two groups are distinguished as 'idiopathic' and 'symptomatic' zoster, but the evidence indicates that both are due to the same virus. 'Symptomatic' zoster may be precipitated by intoxication with arsenic, bismuth, carbon monoxide, and other poisons, and may occur in the course of infections such as pneumonia and tuberculosis or toxic states such as uraemia. It may complicate any lesion of the posterior roots and may therefore follow fracture-dislocation of the spine, secondary

carcinoma of the vertebral column, meningococcal and other forms of meningitis, subarachnoid haemorrhage, syphilitic radiculitis, and spinal tumour. It occasionally follows quite a slight trauma.

Zoster may occur at any age, but is rare in infancy and more frequent in the second half of life than in the first. It is most often seen in patients over 50.

The incubation period is from seven to twenty-four days, and is usually about a fortnight.

Symptoms.

General Symptoms.

The eruption is often preceded by a disturbance of the general health and sometimes by fever, and there is enlargement of the lymph nodes draining the affected area of skin. The general symptoms are usually slight but may be severe in the aged.

Zoster of the Limbs and Trunk.

The first local symptom is usually pain in the segment or segments involved, which is burning or shooting in character and is often associated with hyperalgesia of the area of skin supplied by the affected nerve-roots. Three or four days after the onset of pain the eruption appears as a series of localized papules which develop into vesicles grouped together upon an erythematous base (Fig. 40). The eruption, like the other symptoms, possesses a segmental distribution. After a few days the eruption fades, the vesicles drying into crusts which separate, leaving small permanent scars in the skin. The subsidence of the eruption is often associated with some loss of sensibility in the affected segments. The skin may become partially or completely analgesic, though the pain may persist, the association of pain with sensory loss being sometimes described as anaesthesia dolorosa. Thermal and postural sensibility may also be impaired. Pain may persist for weeks or months or indefinitely after the eruption, and this 'post-herpetic neuralgia' is the more likely to occur the older the patient. Severe itching is sometimes a troublesome sequel.

Segmental Complications of Zoster.

In addition to involving the first sensory neurone and the skin, zoster may cause a disturbance of function of other structures innervated by the spinal segment affected. Muscular wasting of segmental distribution is a rare accompaniment of zoster and is probably due to an extension of the infection from the posterior to the anterior horns of grey matter in the spinal cord. Thus I have seen atrophic paralysis of the muscles supplied by the fifth cervical

segment and also paralysis of the abdominal wall, the latter leading to pseudo-hernia. These palsies are usually permanent. Visceral manifestations of zoster may also occur. Arthritis is rare, but I have seen two cases. It has been described only in the joints of the hand and wrist as a complication of zoster involving the upper limb. There is severe pain and peri-articular swelling with much limitation of move-

Fig. 40. Herpes zoster eruption over lumbar 1 and 2 radicular cutaneous areas.

ment, which is likely to be permanent. Radiographically the bones show only rarefaction. Other visceral manifestations of zoster which have recently been reported include zoster of the pleura and urinary bladder and symptoms resembling those of duodenal ulceration.

Ophthalmic Zoster.

When the zoster virus invades the Gasserian ganglion the eruption appears in some part of the cutaneous distribution of the trigeminal nerve, being usually confined to one division. When the ophthalmic division is involved the cornea may be attacked, usually only when the eruption appears on the part of the nose supplied by the nasociliary branch, as Jonathan Hutchinson pointed out. The corneal lesion takes the form of small, round infiltrations in the more superficial layers of the substantia propria of the cornea. Other

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orbital structures may be involved, the most serious complication, fortunately a rare one, being optic neuritis, followed by atrophy and leading to blindness. Oculomotor paralyses may occur, the third nerve being more often affected than the fourth and sixth. Trigeminal zoster, like zoster elsewhere, may be either idiopathic or symptomatic. In the latter case it may follow any intracranial lesion of the fifth nerve, even alcoholic injection of the Gasserian ganglion.

Geniculate Zoster.

Zoster may infect the geniculate ganglion (Ramsay Hunt's syndrome), in which case the vesicles are found in the auricle and less often on the anterior pillar of the fauces. There is pain in the ear and mastoid region radiating to the anterior pillar of the fauces and to the vertex. Taste is lost in the anterior two-thirds of the tongue on the same side, the region innervated by the geniculate ganglion through the chorda tympani. Almost invariably the infection spreads to the trunk of the facial nerve and leads to facial paralysis, often associated with clonic facial spasm. The eighth nerve may become involved, with resulting deafness or vestibular disturbances.

Meningitis, Encephalitis, and Myelitis.

Some degree of meningeal inflammation is the rule in zoster and is indicated by an excess of mononuclear cells and a raised protein content in the cerebro-spinal fluid, which is almost constantly present. Less frequently clinical signs of meningitis may be observed, headache and cervical rigidity complicating zoster of the Gasserian ganglion, and pains in the lower limbs and Kernig's sign being associated with dorsal and lumbar zoster. Extension of the infection to the substance of the brain or the white matter of the spinal cord is rare   Nevertheless, zoster encephalitis and myelitis have been observed. In the latter myoclonus is not uncommon and intractable hiccup may occur. The pyramidal tract may be invaded, causing spastic weakness of the lower limb on the same side as the eruption.

Generalized Zoster.

Besides the segmental eruption, the patient may exhibit scattered vesicles. These may be few in number—'aberrant vesicles'—or a widespread eruption resembling varicella. Usually the generalized rash appears within three or four days of the outbreak of zoster, but the interval may be longer.

Diagnosis.

The diagnosis of herpes zoster offers little difficulty, as in no other condition is there a vesicular eruption associated with pain and hyperalgesia of a segmental distribution. Herpes febrilis is less pain-

ful, is usually situated in the proximity of a mucous membrane, is often bilateral, and leaves neither residual pain nor scarring. Post-herpetic neuralgia is distinguished from other types of root-pain by the history of the eruption, the scars of which can usually be found. Diagnosis is impossible in the pre-eruptive stage, but the possibility of zoster should be suggested by root pains of sudden onset less than four days before examination.

Prognosis.

The majority of sufferers from zoster recover without residual symptoms, except for scarring of the skin. One attack usually confers permanent immunity. Severe secondary infection of the vesicles is a rare complication. Zoster of the cornea may be followed by corneal ulceration, and the occurrence of optic atrophy has already been mentioned. Recovery usually occurs from facial paralysis following geniculate zoster. Zoster encephalitis is very uncommon, but at least two fatal cases have been reported. The most troublesome sequel of zoster is persistent intractable pain, which may endure for years in elderly patients.

Treatment.

In most cases the treatment of zoster is simple Dusting powder and a dry dressing or collodion are all that are needed for the cutaneous eruption Iodide by the mouth may promote the absorption of exudate in the nervous system and can be combined with analgesics Iodide can also be administered intravenously, and an intravenous injection of 50 c c of 10 per cent. sodium iodide may abort an attack or give immediate relief from pain The subcutaneous injection of $\frac{1}{2}$ to 1 c c pituitrin during the acute stage will often cut short the attack. If convalescent serum is obtainable, 10 c c. may be given subcutaneously. Persistent post-herpetic pain is a very troublesome complication which is very liable to occur in the elderly and aged. In severe cases analgesics are almost useless. It makes life a burden and may lead the patient to the verge of suicide. Morphine is contra-indicated owing to the risk of habit formation. Deep X-ray irradiation of the spinal cord and nerve-roots or of the Gasserian ganglion is often effective in these cases, and should always be tried. It should not be used during the acute stage, but is of little value if left until the condition is chronic. The first treatment should be given three weeks or a month after the onset, if the pain is not subsiding. Subsequent treatments are given at intervals depending upon the degree of reaction. If this fails it is necessary to consider interruption of the pain fibres In trigeminal zoster alcoholic injection of the Gasserian ganglion or of one of its divisions is worth a

trial and sometimes succeeds. Alternatively the sensory root of the ganglion may be divided surgically, as in the surgical treatment of trigeminal neuralgia. In spinal zoster the choice lies between division of the affected posterior roots and section of the spino-thalamic tract above the level of the lesion on the opposite side. The latter is the more likely to be successful, since the lesion may lie within the grey matter of the cord proximal to the point at which the root can be cut, and no benefit will result unless the pain fibres are interrupted on the cerebral side of the lesion. Since the pain fibres ascend for several segments on the same side of the cord before decussating, the section of the opposite spino-thalamic tract must be made at least six spinal segments above the root affected. Otherwise the appropriate fibres may not be interrupted.

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DEMYELINATING DISEASES OF THE NERVOUS SYSTEM

1. CLASSIFICATION

A LARGE and important group of diseases of the nervous system possess, as a common pathological feature, foci in which the myelin sheaths of the nerve fibres are destroyed. These foci, which are mainly situated in the white matter, vary in size, shape, and distribution and also in the acuteness of the pathological process of which they are the result, but they are sufficiently similar in the different diseases to justify the application to the whole group of the name *demyelinating diseases of the nervous system.*

Apart from the fact that all but the most acute forms of demyelinating diseases are sometimes familial, and that the most acute *forms often follow acute infections, especially the exanthemata* caused by viruses such as measles, small-pox, and vaccination, little is known as to the aetiology of this group of disorders. An aetiological classification is therefore impossible.

The attempt to classify them upon a pathological basis encounters the difficulty that although a large number of pathological varieties have been distinguished, they merge into one another to form an almost continuous series. A purely clinical classification is equally unsatisfactory in that it fails to accommodate transitional forms exhibiting features common to two clinical varieties, which can usually clearly be distinguished. The best available classification is a clinico-pathological one, which is based upon the recognition that to a large extent clinical and pathological features can be correlated. Such a classification must be provisional and must be qualified by the recognition of transitional forms. Increased knowledge may well show that clinico-pathological distinctions do not correspond to aetiological differences, but that they are the outcome of differences in respect of the acuteness of the pathological process, which may be influenced by the heredity of the patient, his age, the nature of the precipitating factors and possibly, also, by processes concerned in immunity. We do not yet know even whether these diseases are due to an infection, an intoxication, or, as has been suggested in some cases, an allergic process, or whether they should be classed as deficiency or metabolic disorders. It is uncertain, therefore, when a demyelinating disorder affects the brain and spinal cord, whether encephalitis or encephalopathy, myelitis or myelopathy is the more appropriate term. Encephalitis and

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myelitis are employed here as being less cumbersome and better known. The following is the most convenient clinico-pathological classification:

Variety.	Synonyms.	Incidence.	Distribution of lesion.	Course.
Acute disseminated encephalo-myelitis arising spontaneously	Acute disseminated sclerosis (some cases). Acute focal myelinoclasis	Sporadic; most frequent in young adults.	Patchy in brain and spinal cord, less often optic nerves.	Acute or sub-acute and self-limited.
Acute disseminated encephalo-myelitis following acute infections, e.g. measles, chicken-pox, small-pox, vaccination against small-pox, and "rabies.	Acute perivascular myelinoclasis.	Sporadic, very rarely familial: usually in children or adolescents.	Patchy in brain and spinal cord, tending especially to a perivenous distribution; rarely in optic nerves.	Acute or sub-acute and self-limited.
Disseminated myelitus with optic neuritis.	Neuromyelitis optica. Ophthalmoneuromyelitis (Devic's disease).	Sporadic (once reported in twins), any age from 12 onwards	Massive in optic nerves and chiasma and spinal cord which may undergo softening and cavitation.	Acute or sub-acute in onset; sometimes self limited, sometimes relapsing and progressive.
Disseminated sclerosis.	Insular sclerosis. Multiple sclerosis.	Sporadic, occasionally familial; usually in the first half of adult life.	Patchy in brain, optic nerves, and spinal cord, the lesions being multiple and successive.	Progressive, ranging from acute to extremely chronic with a conspicuous tendency to remissions and relapses.
Diffuse sclerosis.	Encephalitis periaxialis diffusa (Schilder's disease). Centro-lobar sclerosis. Encephaloleukopathia sclerotica. Progressive degenerative sub-cortical encephalopathy. Leukodystrophy. Leuko-encephalopathia myeloclastica primitiva. Encephalomyelomalacia chronica diffusa. Concentric demyelination (Baló's disease). Infantile varieties (Krabbe's disease) (Schol's disease) (Pelzaeus-Merzbacher's disease).	Sporadic and familial; usually in infancy and adolescence, less often in adult life.	Diffuse and massive, usually symmetrical; cerebral much more than "spinal.	Acute, sub-acute, and chronic, steadily progressive or intermittent.

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2. SPONTANEOUS ACUTE DISSEMINATED ENCEPHALO-MYELITIS

Definition: An acute disorder of the nervous system characterized pathologically by focal patches of demyelination which are often perivascular, and clinically by the symptoms of multiple lesions especially optic and retrobulbar neuritis, nystagmus, ocular palsies, inco-ordination, and signs of pyramidal defect.

Synonyms. Acute disseminated sclerosis, acute focal myelinoclasis

Aetiology.

This variety of acute disseminated encephalo-myelitis well illustrates the difficulties of classification of the demyelinating disorders There has been much discussion as to whether it is pathologically distinct from disseminated sclerosis. Many writers, especially Anton and Wohlwill (1912), Redlich (1927), and Spielmeyer (1923) believe that acute disseminated encephalo-myelitis is pathologically distinguishable from acute disseminated sclerosis. Others, such as Fraenkel and Jakob (1913) and most French writers, including Cournand (1930), believe that the two are identical pathologically. Ferraro has recently supported this view. In progressive and fatal cases with lesions identical with the acute lesions of disseminated sclerosis there is no way of distinguishing the two conditions, but in other cases, clinically similar, recovery occurs and the patient does not relapse. It is such cases which justify the distinction of this form of disseminated encephalo-myelitis from disseminated sclerosis

Nothing is known as to the true nature of this disorder. Though the general clinical picture is one of infection no organism has ever been demonstrated in the nervous system, and if the cause is infective we do not know whether the changes in the nervous system are a reaction to the presence of an organism there or are produced by the toxins from, or an allergic reaction to, organisms at a distance. In a few cases symptoms have developed after an acute febrile illness described as influenza, or after acute gastro-enteritis. The disorder usually affects the young adult, but may occur at any age. Females appear to suffer rather more frequently than males.

Pathology.

Since the view is taken that the pathological picture described by Marsden and Hurst (1932) as acute focal myelinoclasis is identical with that of the acute lesions of disseminated sclerosis, it need be only briefly described. Patches of demyelination are scattered throughout the cerebral hemispheres, cerebellum, brain-stem, and spinal cord and predominate in the white matter. The patches are sharply cut and may be perivascular. Within the patches the axis cylinders may be severely damaged or almost intact. Glia cells undergo hyperplasia, especially at the periphery. The blood-vessels are generally dilated and surrounded by lymphocytes, plasma cells, and compound granular corpuscles filled with fatty material. The meninges occasionally show lymphocytic infiltration. The optic nerves, chiasma, and tracts often exhibit similar demyelinating lesions.

Symptoms.

Symptoms usually develop acutely, with or without fever. Headache, vomiting, and giddiness are common at the onset, and delirium occurs in severe cases. The symptoms may be predominantly cerebral, predominantly spinal, or both brain and cord may be diffusely affected. There is a tendency for the infection to extend to hitherto unaffected parts of the nervous system after a lapse of days or even weeks. The symptoms of the cerebral type include mental changes, convulsions, aphasia, hemiplegia, hemianopia, nystagmus, and ataxia of the upper limbs. Optic neuritis may occur, usually bilaterally. Cranial nerve palsies are comparatively uncommon, except for facial paresis, and diplopia is rare. Symptoms of meningeal irritation are usually absent. In the spinal type pains in the back and limbs or with a girdle distribution are common. Paraesthesiae may occur. Paraplegia of varying severity is usually present, associated with sensory loss, which may be confined either to postural sensibility and passive movement, or to appreciation of pain, heat, and cold. A partial or complete Brown-Séquard syndrome is not rare. Bladder disturbances are present in the more severe cases of paraplegia. The tendon reflexes may be exaggerated, but are not uncommonly diminished or lost. The plantars are frequently extensor. The cerebro-spinal fluid frequently shows no abnormality, but may exhibit a rise in protein or slight pleocytosis.

Diagnosis.

Cases with an acute or fulminating onset require to be distinguished from meningitis and from other forms of encephalitis, especially

encephalitis lethargica, and from poliomyelitis. Although signs of meningeal irritation may be present in the most acute cases, especially in childhood, the cerebro-spinal fluid usually shows no abnormality. In the exceptional cases in which a pleocytosis is present the cells are mononuclear. The absence of a polymorphonuclear pleocytosis differentiates these acute cases from meningitis due to pyogenic organisms, and the acute onset and normal chloride content of the cerebro-spinal fluid distinguish them from tuberculous meningitis. Acute disseminated encephalo-myelitis is distinguished from encephalitis lethargica by the infrequency of ocular palsies, and especially of pupillary abnormalities, and by the frequent occurrence of symptoms of massive lesions of the cerebral hemispheres, especially aphasia and hemiplegia. The diagnosis from poliomyelitis is based upon the absence of muscular wasting, the frequent occurrence of extensor plantar responses, and the characteristics of the cerebro-spinal fluid, which in acute disseminated encephalo-myelitis is usually normal, while in the former it always exhibits a marked pleocytosis, composed at the onset of both polymorphonuclear and mononuclear cells, and after the first few days of mononuclear cells only.

When the onset of acute disseminated encephalo-myelitis is subacute it has to be distinguished from disseminated sclerosis. This diagnosis may be difficult, but points in favour of acute disseminated encephalo-myelitis are a febrile onset, impairment of consciousness during the acute stage, the simultaneous occurrence of multiple lesions, the presence of bilateral optic neuritis, the infrequent occurrence of diplopia, the presence of pain in the back and limbs at the onset, involvement of the spino-thalamic tracts, leading to analgesia and thermo-anaesthesia, and loss of the tendon reflexes. When a patient is seen some time after the onset, the symptoms may be indistinguishable from those of disseminated sclerosis, and the diagnosis can then be based only upon the history of the acute onset and the symptoms of the early stages.

Prognosis.

Prognosis is good, only a small proportion of patients succumbing, either after a phase of deepening coma or from intercurrent disease, such as pneumonia or urinary infection. In the majority of cases, after the acute stage, lasting two or three weeks, recovery begins and in many cases is remarkably complete, though it may be interrupted by relapses due to extension of the infection to fresh regions of the nervous system. In a small proportion of cases there may be permanent motor weakness, sensory loss, or reflex abnormalities.

Treatment.

In the most acute cases the most valuable form of treatment is drainage of the nervous system by lumbar puncture, repeated, if necessary, twice or thrice daily. When the patient is comatose the intravenous injection of hypertonic sucrose solution may prove beneficial by reducing cerebral oedema, 25 to 100 c.c. of a 50 per cent. solution being given, according to the age of the patient. Otherwise treatment is symptomatic. The treatment of encephalitis complicating vaccination and the specific fevers and of disseminated myelitis with optic neuritis is described elsewhere.

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3 ACUTE DISSEMINATED ENCEPHALO-MYELITIS COMPLICATING ACUTE INFECTIOUS DISEASES OF CHILDHOOD

Definition: An acute disorder characterized by demyelination of the nervous system, usually with a perivascular distribution, and by symptoms of damage to the brain and spinal cord, especially
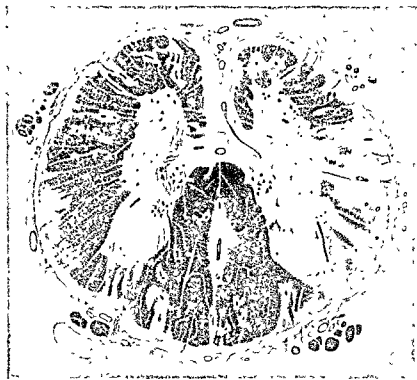
FIG. 50. Post-vaccinal encephalo-myelitis Spinal cord, T. 9. Perivascular and marginal zones of demyelination and a large area of confluent demyelination in the left lateral column and grey matter. (Kindly lent by Prof. H. M. Turnbull.)

in the white matter, occurring in the course of infection with the causal virus of one of the exanthemata, such as measles, German measles, small-pox, vaccination, and probably mumps and chicken-pox, and antirabic inoculation.

Synonyms: Acute perivascular myelinoclasis.

Pathology.

Naked-eye changes consist merely of congestion and oedema of the nervous system Microscopically (Fig. 50) there is marked peri-

vascular infiltration of the brain and spinal cord with lymphocytes and plasma cells both within the perivascular spaces and still more conspicuously at a greater distance from the vessels. In the white matter the most striking feature is the presence of zones of demyelination, that is, loss of the myelin sheaths of the neurones, around the vessels, especially the veins. The grey matter also shows degeneration and infiltration. The most intense changes are found in the lumbar and upper sacral regions of the spinal cord, and in the pons. In the midbrain the substantia nigra is the structure most affected. Inflammatory changes may be present throughout the whole length of the nervous system. Meningeal infiltration is relatively slight. Herkenrath (1935) reports a case of recovery from post-vaccinal encephalitis followed by death from another cause eighteen months later. The nervous system showed no abnormality except some fat-laden scavenger cells in the perivascular spaces of the cerebellum, pons, medulla, and spinal cord. It is inferred that the process which acts in perivascular demyelination is capable of complete reversal results ending in clinical and anatomical recovery.

Aetiology.

The most obvious explanation of the aetiology of this form of encephalo-myelitis is that the changes in the nervous system are the direct result of its invasion by the virus of the exanthem, which has occasionally been found in the nervous system after the development of encephalitis. This view, however, now has few adherents since it has not been possible to produce experimentally the pathological picture of acute perivascular myelinoclasis by means of the virus in question, and inoculation of the nervous system with vaccinial virus and with rabies virus does not cause demyelination. Moreover, it seems unlikely that an identical pathological picture would be produced by so many different viruses. An alternative view proposed is that the encephalitis is due to some other virus common to all the patients and aroused into activity by the exanthem. This would explain the common pathological features and also perhaps the increased incidence of this form of encephalitis during recent years. It would also explain the occasional spontaneous cases of acute perivascular myelinoclasis arising unpreceded by an exanthem. Nevertheless no demyelinating virus has ever been shown to exist and all known neurotropic viruses produce quite different pathological changes, so that many will agree with Hurst (1935) that there is no evidence that acute disseminated encephalomyelitis is due to a virus.

A third hypothesis postulates some unusual process intervening between the original infection and the change in the nervous system.

Thus Glanzman (1927) believes that the encephalitis is the outcome of an allergic or hyperergic process, the nervous system having in some way become sensitized to the original virus. Van Bogaert (1932, 1933) considers that the involvement of the nervous system is due to a lack of the normal defensive reaction of the skin and explains the occasional occurrence of multiple cases in one family as a result of inherited deficiency of the capacity for developing immunity. Finley (1937, 1938) on the basis of the incubation period links the encephalitis with the general eruption and a coincident allergic reaction in the brain. No explanation is completely satisfactory, but the last is perhaps the most suggestive and accords best with the therapeutic value of immune serum and with the observations of Rivers and Schwentker (1935) that a demyelinating encephalo-myelitis could be produced in monkeys by repeated injections of brain material and with a case reported by Russell (1937) in which perivascular areas of demyelination occurred during arsphenamine medication.

(For the clinical features of the different varieties see below)

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Post-Vaccinal Encephalo-myelitis

Aetiology.

Pathology.

Epidemiology.

Nervous complications, for example hemiplegia, following vaccination have been known since 1860, but appear to have been isolated occurrences until 1922, since when epidemics of post-vaccinal encephalo-myelitis have occurred. Ninety-three cases were reported in England between November 1922 and November 1927, and one hundred and twenty-four cases had been observed in Holland prior to the latter date. Cases have been observed elsewhere in Europe and the United States, though they have been much rarer than in the countries mentioned. Post-vaccinal encephalo-myelitis is a rare complication of vaccination. In Holland it has been estimated that one case occurred in over 5,000 persons vaccinated. It follows primary vaccination much more frequently than revaccination, the incidence in Holland being approximately one case in 2,300 primary vaccinations and one case in 50,000 revaccinations. It is practically unknown in infants vaccinated under the age of 1 year and most cases have occurred in children of school age. Though no age is exempt, it is rare after 30. Both sexes are affected equally.

The condition has occurred in epidemics which have coincided with an increase in the number of persons vaccinated owing to the prevalence of small-pox. In the English outbreak of 1923 the 31 cases reported were distributed across the country from Exeter in the south-west to Morpeth in the north-east, with an extension to London and the home counties. There is no evidence of spread of the disorder by contagion or by any other method of dissemination from one place to another, but it has been noticed that there are often proportionately more cases in small communities and rural areas than in large towns. In several cases two members of the same family who had been vaccinated at the same time both developed encephalo-myelitis. The source of vaccine lymph does not appear to be of any aetiological significance.

Symptoms.

Incubation Period.

In most cases the symptoms of encephalo-myelitis develop between the tenth and the twelfth days after vaccination, though the onset has occurred as early as the second day or as late as the twenty-fifth. There is evidence that when the disorder follows revaccination the incubation period is less than when it occurs after primary vaccination.

Symptoms.

The onset is usually rapid and is characterized by headache, vomiting, drowsiness, fever, and in some cases convulsions. When

fully developed the clinical picture is usually that of meningeal irritation associated with widespread disturbance of function of the brain and spinal cord. In severe cases drowsiness passes into stupor and coma. Cervical rigidity and Kernig's sign are often present The ocular fundi are usually normal, but transient papilloedema has *occasionally been observed. The incidence of ocular abnormalities* is variable. In some cases impairment of the pupillary reflexes and ocular palsies have been present. In others they have not been noted. Trismus has frequently been described, and more than one case has been mistaken for tetanus on account of this symptom. Flaccid paralysis of some or all of the limbs often develops, associated with loss of tendon reflexes and extensor plantar responses. Retention or incontinence of urine and faeces is the rule in severe cases. Sensory loss is inconstant, but may be marked when the spinal cord is severely affected. The cerebro-spinal fluid is frequently normal, though under increased pressure. An excess of mononuclear cells and of protein may be found. The cutaneous site of vaccination shows the usual inflammatory changes corresponding to the stage at which the patient comes under observation. Not uncommonly there is a severe local reaction, and in a few cases a generalized vaccinial rash has been observed.

Diagnosis.

The diagnosis rarely presents any difficulty, since there is a history of recent vaccination and the cutaneous lesions are still visible. Apart from this the clinical picture cannot be distinguished from other forms of acute disseminated encephalo-myelitis occurring spontaneously or complicating the exanthemata. The severe involvement of the substance of the nervous system indicated by flaccid paralysis distinguishes the condition from meningitis, while the presence of signs of meningeal irritation and the subsequent occurrence of convulsions, trismus, and paralysis of the limbs, together with the inconstancy of ocular abnormalities, distinguish it from epidemic encephalitis lethargica. Post-vaccinal encephalo-myelitis is distinguished from poliomyelitis by the fact that the paralyses, though flaccid, are not associated with wasting of the muscles, and by the presence of extensor plantar responses and in some cases of sensory loss. In poliomyelitis, moreover, the mental state of the patient is usually little affected.

Prognosis.

The mortality rate is high, ranging from 30 per cent. to over 50 per cent. in different epidemics. In most fatal cases the patient dies in coma from medullary paralysis within a few days of the onset of the

illness. Less frequently death is due to broncho-pneumonia or infection of the urinary tract. If recovery occurs it is usually remarkably complete and residual symptoms are exceptional. In some cases, however, there may be some persistent loss of power or sensory loss or, in the case of young children, mental defect.

Prophylaxis.

With the object of preventing post-vaccinal encephalo-myelitis as far as possible, the Minister of Health has made a number of recommendations contained in the Vaccination Order, 1929. Since the main incidence of post-vaccinal encephalo-myelitis falls upon previously unvaccinated adolescents, the opinion is expressed that 'as long as the small-pox prevalent in this country retains its present mild character, it is not generally expedient to press for the vaccination of persons of these ages who have not previously been vaccinated, unless they have been in personal contact with a case of small-pox or directly exposed to small-pox infection'. Only subjects *who are in good health should be vaccinated, and subjects who have* recently been exposed to measles, scarlatina, diphtheria, or erysipelas should be vaccinated *only in cases of urgent necessity. In all* ordinary cases of vaccination or revaccination the operation should be carried out in one insertion, preferably by a single linear incision or scratch, not more than a quarter of an inch long, merely through the epidermis, in the long axis of the limb. But where the maximal protection against small-pox is desired, the number of insertions may be increased, but should not exceed four. In no circumstances should the vaccinated area be cross-scarified or cross-hatched.

Treatment.

The most effective treatment of post-vaccinal encephalo-myelitis appears to be the administration of immune serum. This is often obtainable from a relative who has been vaccinated at the same time *as the patient. In some cases that of an individual vaccinated several* years previously has proved effective. In case human immune serum is not available, *antivaccinial horse serum has been prepared at the* Lister Institute. Immune serum has been administered intrathecally, but appears to be equally effective if given intravenously in a dose of 10 c.c Good results have also been claimed for the intramuscular injection of 10 c.c. of citrated whole blood, which possesses the advantage of being much more easily prepared than blood serum The immune serum or blood should be given at the earliest possible moment. Striking and rapid recovery has followed its use. Repeated lumbar puncture is a valuable adjuvant method of treatment.

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ENCEPHALO-MYELITIS COMPLICATING SMALL-POX

The occurrence of nervous symptoms as a complication of small-pox has been known for many years, but is a rare event, having been observed in only approximately 2·5 cases per 1,000 persons suffering from small-pox. The pathology of the condition was little studied until lately, but the recent investigations of Troup and Hurst and of Mackintosh and Scarff have shown that the pathological changes in the nervous system are indistinguishable from those of post-vaccinal encephalo-myelitis. In some cases bulbar symptoms, especially dysarthria, have been prominent, and these are sometimes accompanied by paralysis of the limbs. In other cases bulbar symptoms are absent and paraplegia occurs, with or without sphincter disturbances and impairment of sensibility. Mental changes are sometimes present. In many cases recovery occurs and is strikingly complete, but the patient may die during the acute attack or subsequently, from urinary infection or other complications of paraplegia. Treatment is the same as for post-vaccinal encephalitis.

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ENCEPHALO-MYELITIS COMPLICATING MEASLES

Aetiology.

See p. 476.

Pathology.

See p. 475.

Symptoms.

Nervous complications of measles have been known for over a century, but appear to have become more common during recent years. The onset of symptoms is usually four to six days after the beginning of the illness when the fever has fallen and the rash is fading. Ford (1928) has reviewed the literature and distinguishes a number of clinical types. It is probable that acute perivascular myelinoclasis is not the pathological basis of all the nervous complications of measles.

(1) The nervous symptoms may be relatively mild and transient and present a clinical picture resembling 'meningism' or 'serous meningitis'. In such cases headache, stupor, signs of meningeal irritation, and sometimes convulsions occur, but focal lesions of the substance of the nervous system are absent.

(2) Multiple focal or diffuse lesions of the nervous system may occur, involving the cerebral cortex, basal ganglia, brain-stem, cerebellum, and spinal cord in various combinations.

(3) There may be a single focal cerebral lesion, hemiplegia and aphasia being the commonest.

(4) The symptoms may be predominantly those of cerebellar deficiency.

(5) The spinal cord may be mainly affected, the clinical picture being an acute ascending paralysis leading to paraplegia, with or without concurrent involvement of the brain.

(6) Other nervous symptoms are rare. Papilloedema has been observed, and symptoms resembling those of the toxic psychoses may occur. The cerebro-spinal fluid may be normal or may show a moderate increase in lymphocytes and protein.

Diagnosis.

The diagnosis is usually easy, since the measles rash is generally present when the nervous symptoms develop. If the attack of measles has passed unnoticed the disorder cannot be distinguished from other forms of acute disseminated encephalo-myelitis.

Prognosis.

The mortality rate is 10 per cent. (Ford). Complete recovery, however, occurs in only 25 per cent., the remaining 65 per cent. being left with residual symptoms, of which the most important are hemiplegia, ataxia, mental defect or change of personality, and epilepsy.

Treatment.

The child should be given convalescent serum, if this is obtainable, preferably from an individual who has had measles not more than a year previously. The serum should be given intramuscularly, or in severe cases intravenously, in doses of 10 c.c., which may be repeated as required.

Daily lumbar puncture should be carried out during the acute stage.

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ENCEPHALO-MYELITIS COMPLICATING GERMAN MEASLES

Nervous complications of German measles are very rare, but in at least one case the pathological picture has been that of acute disseminated encephalo-myelitis with perivascular demyelination. As in

the case of mumps, however, other clinical pictures are seen. Meningeal symptoms have been reported in a few cases and both ascending paralysis of the Landry type and polyneuritis have been encountered.

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ENCEPHALO-MYELITIS COMPLICATING CHICKEN-POX

Encephalitis and myelitis are rare complications of chicken-pox, but more than 80 cases have been reported during recent years.

Pathology.

Owing to the benign nature of the disorder there have been few opportunities of studying its pathology. Although perivascular infiltration and demyelination have been described in 2 cases, areas thus affected were very circumscribed in both and other changes not part of the pathological picture of the demyelinating diseases of the nervous system have been observed, particularly degeneration of ganglion cells. Van Bogaert has reported circumscribed foci in the white matter and a more diffuse affection of the grey matter of the cerebrum and cerebellum, lesions resembling young plaques of disseminated sclerosis. Miget has reported a case in which inflammatory infiltration of the leptomeninges was the most conspicuous feature.

Aetiology.

It is not certain, therefore, whether encephalitis complicating chicken-pox belongs to the same group as encephalitis complicating vaccination, measles, and small-pox. The causal organism of chicken-pox is closely allied to, if not identical with, that of herpes zoster, which is a neurotropic agent probably a virus. It is possible that the potential neurotropic propensity of the virus of varicella leads it at times to invade the nervous system and that the encephalitis so produced is different from the demyelinating form. Almost all the recorded cases have occurred in children at an average age of 4 years.

Symptoms.

Symptoms of involvement of the nervous system develop in such cases between the fifth and the twentieth day after the appearance

of the rash, usually during the first half of the second week. The onset is acute, and is characterized by fever, headache, vomiting, and giddiness, and sometimes by delirium. The disturbance may be mainly meningeal, mainly cerebral, or mainly spinal. The meningeal form is characterized by the usual symptoms of meningitis with little or no evidence of involvement of the substance of the nervous system. A cerebral incidence is twice as common as a spinal. In the former, inco-ordination is the commonest symptom, occurring with or without involuntary movements. The ataxia is often so gross as to render the child incapable of walking. Tremor and choreic or choreo-athetoid movements occur in some cases. Signs of pyramidal lesions may be present, but diplegia and hemiplegia are rare. Ophthalmoplegia has been observed. The spinal lesion usually produces the picture of a transverse myelitis at the dorsal level of the cord. The spinal fluid may be normal, or may show an excess of cells, usually mononuclear.

Diagnosis.

The cause of the nervous symptoms is evident when the diagnosis of chicken-pox has already been made. If, however, this has passed unnoticed, the encephalo-myelitis cannot be distinguished from other forms of acute disseminated encephalo-myelitis, except that the frequent involvement of the cerebellum appears to be peculiar to encephalitis complicating chicken-pox.

Prognosis.

The prognosis is good, both as to life and as to recovery of function. Death is very rare, and in 90 per cent. of cases complete recovery occurs.

Treatment.

The child should be given convalescent serum, if this is obtainable, preferably from an individual who has had chicken-pox not more than a year previously. The serum should be given intramuscularly or in severe cases intravenously, in doses of 10 c.c., which may be repeated as required. Daily lumbar puncture should be carried out during the acute stage.

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4 DISSEMINATED MYELITIS WITH OPTIC NEURITIS

Synonyms: Acute disseminated myelitis; diffuse myelitis with optic neuritis; neuro-myelitis optica; ophthalmoneuromyelitis; Devic's disease.

Definition: A form of subacute encephalo-myelitis characterized by massive demyelination of the optic nerves and spinal cord, sometimes running a self-limited and sometimes a progressive course.

Pathology.

Both optic nerves and spinal cord exhibit massive demyelination. The loss of myelin sheaths is found in the optic nerves and chiasma, and in the spinal cord may be limited to a few segments, usually in the lower cervical and upper dorsal region, or may be more diffuse, extending through the greater part of the cord's length. In severe cases cavitation may occur. Marked perivascular infiltration is not only present in the demyelinated areas but may be found throughout the nervous system. The infiltrating cells are principally mononuclear, but polymorphonuclear cells may also be present. In the demyelinated areas there is a great multiplication of vessels surrounded by many fat granule cells and also neuroglial cells, though with little formation of new neuroglial fibres. To the naked eye the affected areas are swollen, congested, and softened.

Aetiology.

Both pathologically and clinically this disorder is closely related to disseminated sclerosis, differing from the latter, however, in the tendency to a more massive and necrotic type of lesion, and the occurrence of recovery in some cases. The same problems of aetiology arise as in the case of disseminated sclerosis, and only when they are solved will it be possible to decide the relationship of the two diseases. The cause of Devic's disease is unknown. It is rare and affects both sexes at all ages from 12 to 60. McAlpine (1938) has reported its occurrence in identical twins.

Symptoms.

Either the ocular or the spinal lesion may develop first, and these events may be separated by days or weeks, or both may occur simultaneously. Usually one eye is first affected, to be followed by the other after an interval varying from a few hours to several weeks. Rarely the onset of the myelitis intervenes between the affection of the two eyes.

The ocular lesion may be a true optic neuritis or a retrobulbar neuritis, depending upon whether it is situated sufficiently anteriorly to involve the optic disks. In the former case papilloedema is present, though the swelling is usually slight; in the latter the disks are normal. The characteristic field defect is a bilateral central scotoma. In severe cases blindness may be complete or almost so. Homonymous field defects have been described. The two eyes are often unequally affected. Pain in the eyes is often severe and is accentuated by moving them and by pressure upon the globes.

The spinal cord lesion, the onset of which may be associated with severe pain in the back and limbs, leads to the usual symptoms of transverse myelitis, with paralysis of the upper motor neurone type and loss of some or all forms of sensibility below the level of the lesion and loss of sphincter control. When, as frequently happens, the cervical region of the cord is involved a quadriplegia results.

The cerebro-spinal fluid may show no abnormality or there may be an increase of protein and globulin and an excess of cells, which are usually mononuclear, though occasionally polymorphonuclear cells have been described. There is no characteristic colloidal gold curve.

It is probable that the disorder may abort after the development of optic neuritis and before the spinal symptoms appear and that the reverse may also occur, so that cases of acute bilateral optic neuritis or retrobulbar neuritis without other symptoms and also cases of acute transverse myelitis without optic neuritis may belong to this group.

Diagnosis.

The presence of bilateral optic neuritis may suggest a diagnosis of intracranial tumour. In optic neuritis, however, the papilloedema is slight in proportion to the severity of the loss of vision and the characteristic field defect is bilateral central scotomas in contrast to the peripheral constriction of the fields associated with papilloedema in increased intracranial pressure. Moreover, in cases of optic neuritis headache and vomiting are absent, though pain in the eyes may be severe.

Disseminated sclerosis may be simulated on account of the association of optic or retrobulbar neuritis with a spinal lesion. In disseminated sclerosis, however, optic neuritis is very rarely simultaneously bilateral and the coincidence of bilateral optic neuritis with myelitis is unknown.

Syphilitic myelitis can be distinguished by serological tests.

Prognosis.

The mortality rate is about 50 per cent., death occurring either from respiratory paralysis as a result of the upward spread of the myelitis, or from infections of the skin or urinary tract complicating the paraplegia. If the patient survives, recovery is often remarkably complete. Complete blindness may be followed by a considerable return of vision, though some degree of optic atrophy is likely to persist. Similarly, the functions of the spinal cord may be largely, if not completely, restored. Recovery, once achieved, may be permanent, but progressive and relapsing cases occur.

Treatment.

In the absence of knowledge of the cause, treatment can only be symptomatic. Pain in the eyes should be treated by mustard leaves applied to the temples. Large doses of iodide may hasten removal of inflammatory products in the nervous system. The administration of arsenic, whether by the mouth or intravenously, is contra-indicated. The usual measures for the care of the skin, urinary and intestinal tracts, and musculature, which are required in paraplegia, will be necessary.

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5. DISSEMINATED SCLEROSIS

Synonyms: Multiple sclerosis ; insular sclerosis.

Definition: A disease of unknown aetiology characterized pathologically by the widespread occurrence in the nervous system of patches of demyelination followed by gliosis. In most cases the early manifestations of the disease are followed by conspicuous improvement, so that remissions and relapses are a striking feature of the disorder, the course of which may thus be prolonged for many years. The early symptoms are often those of focal lesions of the nervous system, while the later clinical picture is one of progressive dissemination tending to produce the classical features of nystagmus, dysarthria, intention tremor, and ataxic paraplegia.

Pathology.

The pathological 'unit' in disseminated sclerosis is a circumscribed patch of nervous tissue in which the pathological process begins with destruction of the myelin sheaths of the nerve fibres and to a much less extent of the axis cylinders, and ends with the formation of a 'sclerotic plaque' (Fig. 51). These patches predominantly affect the white matter of the brain and spinal cord. They are sometimes found in the grey matter of the cerebral cortex and in the cranial and spinal nerve roots, rarely in the grey matter of the spinal cord. Many writers have stressed the perivascular distribution of many of the patches, though Dawson points out that 'the changes appear within but do not coincide with the area of distribution of the arteries'. Putnam emphasizes the relationship of the patches to the cerebral venules. The optic nerves and chiasma, the neighbourhood of the cerebral ventricles, and the subpial region of the spinal cord are favourite sites.

To the naked eye the sclerotic plaque appears slightly sunken, greyish, and more translucent than normal nervous tissue. In the acute stage of a patch the blood-vessels are dilated and the perivascular spaces contain fat-granule cells and frequently also lymphocytes and plasma cells. The myelin of the nerve sheaths is undergoing degeneration and the axis-cylinders show diffuse or irregular swellings

and other abnormalities. Even at this stage, as Greenfield and King point out, there is a conspicuous proliferation of the fibroglia. In late patches the destroyed myelin has been removed; the axis-cylinders are reduced in number, and some of those persisting show
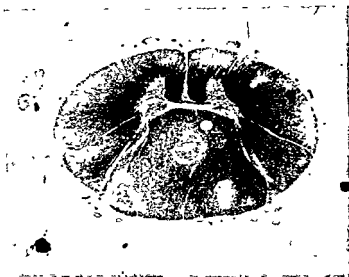
Fig. 51. Disseminated sclerosis: spinal cord. Th. IX.

abnormalities, and there is a dense condensation of the original glial meshwork.

Aetiology.

Earlier pathologists regarded the gliosis as the primary change, hence the name disseminated 'sclerosis'. The modern view is that the glial overgrowth is either a scar reaction to the earlier inflammatory and demyelinating process, or that it is simultaneously evoked by the same agent which causes the destruction of the myelin sheaths. A large variety of aetiological theories have been proposed. The disease has been attributed to infection by a spirochaete (Steiner and others) or a filterable virus, but it has never been transmitted to animals and the negative evidence against infection far outweighs the positive. The modern tendency is to stress constitutional factors. A myelin-splitting ferment in the blood has been described (Brickner). Putnam attributes the patches to thrombosis in the cerebral venules and links this with a tendency to increased coagulability of the blood described by Simon and Solomon. Dattner

finds a high incidence of a positive complement fixation reaction for tuberculosis and of gastric hypochlorhydria or achlorhydria. Poisoning with lead has also been invoked.

The Role of Inherited Predisposition.

Multiple cases of disseminated sclerosis in the same family are not uncommon. Curtius in 1933 collected 84 references to this in the literature. In most instances two siblings are affected. Affection of two successive generations is less common. The proportion of patients with disseminated sclerosis who have a near relative similarly affected is probably between 5 and 10 per cent. This is much lower than that found in the case of diseases in the aetiology of which heredity is the principal factor. Curtius, however, has found evidence that a general neuropathic tendency may play a part in causation. The parents, siblings, nephews, and nieces of 56 patients with disseminated sclerosis showed a far higher incidence of nervous and mental diseases than a control group of 56 patients with fractures.

Precipitating Factors.

A large variety of events may immediately precede the onset of the illness and may reasonably be regarded as precipitating factors though their mode of operation is unknown. Such precipitating factors were described by 24 out of 63 patients seen within a short time of the onset of the first symptoms. They include influenza and infections of the upper respiratory tract, the specific fevers, pregnancy, the puerperium and lactation, surgical operations, the extraction of teeth, carbon monoxide poisoning, and electric shock Trauma requires special consideration. The proportion of cases in which the onset of the disease follows trauma is small, no more than 5 to 10 per cent , and it is possible that in some cases the trauma is the result of the disability due to the disease and not its cause. There is no conclusive statistical evidence that trauma is an aetiological factor, but it is possible that in isolated cases it operates as a precipitating factor like those just mentioned.

Distribution, Age, and Sex.

Disseminated sclerosis is most prevalent in Northern Europe and Switzerland. It is much less common in North America and rare in the tropical countries. In England and Wales there are approximately 200 cases per million living persons. In Switzerland the incidence is nearly double, and in the United States only one-quarter of the English figure. The urban incidence is slightly higher than the rural, but occupation appears to be of no importance in aetiology.

The disease principally attacks young adults. In two-thirds of all

cases it begins between 20 and 40, rather more often in the third than the fourth decade. Its occurrence below the age of 10 is doubtful, but it is occasionally seen in children between the ages of 12 and 15. In only 7 per cent. of cases is the age of onset over 50. In most published series males have been reported more often than females, but in England the reverse is the case, female patients out-numbering males in the ratio of 3 to 2.

Symptoms.
The Clinical Picture.

The natural history of the disease produces a very varied clinical picture. In the early stages it is often that of a single focal lesion, acute or during a remission, quiescent. As time goes on the cumulative effects of earlier lesions constitute a persistent background of incapacity upon which fresh disabilities due to new lesions are superimposed. The early stages thus usually show long and often remarkably complete remissions, while later the patient's condition fluctuates only to the small extent that fresh lesions temporarily regress.

Mode of Onset.

The onset of the illness is usually the rapid development, within a few hours or a day or two, of symptoms of a single focal lesion of the white matter of the nervous system. Much less often symptoms appear insidiously. In a series of 100 consecutive patients the first symptom noticed was as follows:

Weakness or loss of control over limbs.   *No.*

Involving both lower limbs	18
Involving one lower limb	14
Involving one upper limb	9
Involving one upper and one lower limb	7
Involving all four limbs	2
	— 50

Visual symptoms.

'Blindness' in one eye	16
Double vision	8
'Dimness' of vision	4
Homonymous field defect	1
	— 29

Sensory symptoms.

Numbness and other painless paræsthesiae	11

Miscellaneous symptoms.

Vertigo .	.	.	.	.	.	.	.	2
Tremor .	.	.	.	.	.	.	.	2
Multiple symptoms .	.	.	.	.	.	.	2
Ptosis .	.	.	.	.	.	.	.	1
Loss of taste .	.	.	.	.	.	.	1
Epilepsy	.	.	.	.	.	.	.	1
Impotence	.	.	.	.	.	.	.	1
								— 10

Thus weakness of one or both lower limbs is the first symptom in about one-third of all cases, and a disturbance of vision in almost one-third more. Sensory symptoms which cause no disability are often forgotten and probably occur more frequently than in 11 per cent. Patients who are carefully questioned at the time of onset often describe symptoms of multiple small lesions occurring within a period of a few weeks. Weakness of the lower limbs is the commonest presenting symptom in patients in whom the disease develops insidiously, and in those in whom it begins after 35.

Motor Symptoms.

Motor Weakness. Loss of power in the lower limbs is first manifested as fatiguability or a feeling of heaviness and later as spastic paraplegia Sometimes sudden weakness of one upper limb occurs, often associated with marked loss of postural sensibility in the fingers—the 'useless hand' of Oppenheim. Facial weakness and hemiplegia occur occasionally.

Muscular wasting is very rare owing to the infrequency of involvement of the anterior horn cells in the patches, but an 'amyotrophic' form has been described, and wasting may occur in any group, but most often in the forearms and hands.

Inco-ordination is frequently present. In the upper limbs it usually takes the form of *intention tremor,* a tremor occurring only on voluntary movement and increasing in intensity the greater the accuracy demanded of the movement. In touching the nose with the finger the tremor increases in amplitude as the finger approaches the nose. The same phenomenon is shown if the patient be asked to touch his own nose and the observer's finger alternately, and also in lifting a glass of water to the lips. In the lower limbs inco-ordination is evident in an ataxic gait. Tremor of the head is common in the late stages.

Dysarthria may be due either to spastic weakness or to ataxia of the muscles of articulation or to a combination of these factors. In the early stages articulation may be slurred, later it may become

explosive and almost unintelligible. The 'syllabic' or 'scanning' speech, sometimes regarded as typical, is exceptional. Transitory aphasia is rare.

Sensory Symptoms.

Paraesthesiae occur at some period of the disease in most cases, commonly in the form of numbness and fornication over one side of the face or one upper or lower limb. When there is a patch in the posterior columns of the cervical cord a sensation resembling an electric shock may radiate through the body on flexing the cervical spine. Pain is uncommon except in the back but typical trigeminal neuralgia, which is sometimes bilateral, is occasionally encountered. Objective sensory loss is present in at least 50 per cent. of cases. Defect of postural sensibility and of appreciation of vibration is the commonest disturbance, but cutaneous sensibility may also be impaired. Inability to recognize objects placed in the hand may occur as the result of a plaque in the column of Burdach in the cervical region. There may be a sharply defined upper level of sensory loss on the trunk suggestive of a spinal tumour.

Ocular Symptoms.

Acute unilateral retrobulbar neuritis is one of the most important early symptoms of the disease. It occurs most often between the ages of 20 and 30. The vision of one eye becomes misty and in twenty-four or forty-eight hours is reduced to a perception of hand movement or of light only. The eye is painful on movement and tender on pressure, and there is a central scotoma larger for red and green than white. The optic disk is usually normal in appearance during the acute stage, but if the lesion is near the disk papillitis may occur, though the swelling is usually slight. In a few weeks vision improves, but the residual damage to the nerve manifests itself in some degree of optic atrophy—pallor of the disk, especially in its temporal half—and often a persistent though smaller central scotoma. Permanent blindness is very rare. Simultaneous retrobulbar or optic neuritis in both eyes is uncommon in disseminated sclerosis but undoubtedly occurs. The lesions of the optic nerves may be so insidious as to produce the characteristic temporal pallor of the disk, which is found in over 50 per cent. of cases, without the patient being aware of any impairment of vision. Lesions of the optic chiasma and optic tracts are uncommon, and when they occur cause distinctive defects of the visual fields.

Nystagmus is present in at least 70 per cent. of cases. It is usually absent on central fixation and appears on conjugate deviation both laterally and vertically. The slow phase is towards the central

fixation point and the quick phase away from it. A rotary element is sometimes present, especially on vertical fixation. Nystagmus on central fixation is rarely seen in disseminated sclerosis.

Ocular Paralysis. Paralysis of conjugate ocular deviation may occur as the result of a plaque in the midbrain or pons, but is uncommon: paresis of single ocular muscles occurs in about 6 per cent. of cases; but diplopia without objective ocular palsy is commoner—(34 per cent. of cases). Dissociation of lateral conjugate deviation may occur, the adducting eye being less completely deviated than the abducting. This has been ascribed to a lesion of the posterior longitudinal bundle. I have seen paresis of both internal recti. Ptosis is rare, retraction of the upper lids slightly commoner.

Pupillary Abnormalities. The pupillary reactions are usually normal. Loss of the reaction to light with preservation of that to accommodation is occasionally observed and is more frequently unilateral than in syphilis. Total ophthalmoplegia interna may occur. Paresis of the ocular sympathetic leading to ptosis, enophthalmos, and myosis may be seen as the result of a brain-stem lesion.

Auditory and Vestibular Symptoms.

Deafness is rare, but vertigo is a common and early symptom usually as a mild sense of instability. Sometimes severe vertigo with vomiting and coarse nystagmus occurs in attacks lasting for several days.

Mental Symptoms.

Some reduction in the intellectual efficiency of the patient is not uncommon, but emotional changes are more frequent. The characteristic sense of mental and physical well-being—euphoria—is well known. On the other hand, depression and irritability are sometimes conspicuous. Some loss of control over emotional movements, leading to involuntary laughter and tears, is common, especially in the later stages of the illness. Delusional states and a terminal dementia are sometimes met with.

Reflex Changes.

The length of the pyramidal tracts exposes them to a great chance of injury by some of the multiple lesions, hence the reflex signs of pyramidal damage are frequent. The tendon reflexes are exaggerated. The abdominal reflexes are absent in at least two-thirds of all cases and may be lost at an early stage, and extensor plantar reflexes occur in from 80 to 90 per cent. of cases in the later stages.

Other Symptoms.

Sphincter control is frequently impaired. In the early stages delay or precipitancy of micturition is common. Later retention or reflex evacuation of both urine and faeces may occur.

Pyrexia may develop during acute exacerbations of the disease, which is consequently sometimes described by the patient as having begun with an attack of 'influenza'. *Headache* sometimes occurs.

Convulsions occur in a small proportion of cases and may confuse the diagnosis unless their occasional occurrence is remembered.

Trophic changes are rare, but I have occasionally seen cyanosis of the extremities with extreme dryness of the skin and brittleness of the nails

Cerebro-spinal Fluid

Some abnormality is found in the cerebro-spinal fluid in at least half of all cases. An excess of mononuclear cells is found in about 10 per cent. The most characteristic change is an abnormal colloidal gold curve. This is usually of the 'paretic', less often of the 'luetic' type, one or the other occurring in from 50 to 75 per cent. of cases. The protein is usually normal and the Wassermann reaction is, of course, negative.

Symptom Groups

The extreme variability of the clinical picture justifies the recognition of 'forms' of the disease due to the predominant involvement of different parts of the nervous system.

(1) The classical form of Charcot, with nystagmus, intention tremor, and scanning speech, is comparatively rare, and occurs in only about 10 per cent. of cases.

(2) The generalized form, common among younger patients, is characterized by pallor of the optic disks, nystagmus, slight intention tremor, ataxia, weakness and spasticity of the lower limbs, and defective sphincter control.

(3) Onset with ocular symptoms. Retrobulbar neuritis may be the only symptom for many years.

(4) Hemiplegia may be the first symptom and is usually transitory.

(5) Spinal forms. (*a*) *Progressive spastic paraplegia* may occur with few if any other physical signs, especially in middle-aged patients. (*b*) *Unilateral spinal lesions* occur chiefly in the cervical cord The posterior and lateral columns are usually involved. (*c*) *Sacral form.* A plaque in the conus medullaris may lead to incontinence of urine and faeces, impotence, and anaesthesia in the region of the sacral cutaneous supply.

(6) *Cerebellar, vestibular, pontine, and bulbar forms* are self-explanatory.

(7) *Acute forms.* Occasionally the disease may run an acute or subacute course terminating fatally in three or four months. The onset is rapid; headache, vomiting, and optic neuritis may occur, and cranial nerve palsies are commoner than in the more slowly progressive forms.

Diagnosis.

Disseminated sclerosis must be distinguished from various forms of acute disseminated encephalo-myelitis which cause similar pathological changes in the nervous system. When the onset of encephalo-myelitis is acute and there are severe diffuse lesions with fever and perhaps impairment of consciousness, the diagnosis is not difficult, but, when the symptoms are mild, time alone may enable a benign encephalo-myelitis, recovery from which is complete, to be distinguished from the chronic relapsing disease.

Acute disseminated myelitis with optic neuritis, or *neuro-myelitis optica,* is closely related to disseminated sclerosis, but differs in that when the patient survives the acute attack recovery is often complete. In this disorder the symptoms of optic or retrobulbar neuritis are associated with those of transverse myelitis, both developing within a few weeks. These lesions are not contemporaneous in disseminated sclerosis. Acute bilateral optic or retrobulbar neuritis may occur without myelitis, and also runs a benign course. Although both eyes may be the site of optic or retrobulbar neuritis in disseminated sclerosis, it is rare for them both to be affected simultaneously in this disease.

Meningo-vascular Syphilis. Disseminated sclerosis is distinguished from meningo-vascular syphilis by the rarity of pupillary changes and of diminution of the knee- and ankle-jerks in the former and the absence of a positive Wassermann reaction, which is present in the blood and spinal fluid in most cases of the latter. Moreover, *nystagmus is rare in cerebral syphilis and true intention tremor unknown.*

Tabes may to some extent be simulated by the ataxic gait of disseminated sclerosis, but in the latter this is usually associated with spasticity, the knee- and ankle-jerks being exaggerated and the plantar reflexes extensor, while the pupillary reflexes are normal.

Friedreich's ataxia possesses in common with many cases of disseminated sclerosis nystagmus, absent abdominal reflexes, ataxia of the lower limbs, loss of postural sensibility, and extensor plantar responses. In this disease, however, we find diminution or loss of the ankle-jerks and later of the knee-jerks, scoliosis, and pes cavus,

while the frequent onset in childhood, slow progressive course, and occurrence of multiple cases in one family are distinctive.

Other Familial Ataxias. Some forms of familial ataxia have been described, of which individual cases have been indistinguishable from disseminated sclerosis, e.g. the Drew family described by Ferguson and Critchley. Differential points, however, are the familial incidence, the onset either earlier or later than is usual in disseminated sclerosis, the steadily progressive course, and the occurrence of symptoms, e.g. marked ocular palsies, extrapyramidal signs, and extensive sensory loss, unusual in disseminated sclerosis.

Subacute Combined Degeneration may lead to confusion as a cause of 'ataxic paraplegia'. It begins, however, later in life than most cases of disseminated sclerosis; paraesthesiae appear early and persist, the tendon reflexes in the lower limbs are often lost, and gastric achylia and megalocytic anaemia are distinctive features.

Spinal Tumour. Disseminated sclerosis may closely simulate spinal tumour when it gives rise to progressive spastic paraplegia, with or without sensory loss up to a segmental level, and without evident physical signs above the spinal cord. Such symptoms in a case of spinal tumour would, however, almost certainly be associated with obstruction of the spinal subarachnoid space, demonstrable by Queckenstedt's test, and, if necessary, by radiography of the spinal canal following the intrathecal injection of lipiodol, and with a high protein content of the cerebro-spinal fluid.

Intracranial Tumour may be simulated by disseminated sclerosis either on account of the occurrence of convulsions associated perhaps with a monoplegia, or because of the presence of optic neuritis. Disseminated sclerosis is to be distinguished from tumour by its remittent course, the infrequency and slightness of headache, and the frequent occurrence of signs indicating multiple disseminated lesions. In optic neuritis the swelling of the optic disk is usually slight, but the visual impairment is considerable and involves the central part of the field. In papilloedema due to increased intracranial pressure the swelling is often marked while the visual impairment is slight, and the field defect is a peripheral constriction.

Encephalitis lethargica is distinguished from disseminated sclerosis by the frequent history of an acute attack characterized by lethargy, and by the presence of abnormal pupillary reactions, especially loss of that on convergence, and Parkinsonism, pyramidal lesions being slight or absent and inco-ordination rare.

Hysteria can be confused with disseminated sclerosis only through neglect to make a thorough examination of the nervous system. Such early symptoms as giddiness, paraesthesiae, and paresis may

superficially suggest hysteria, but these are rarely present without some sign of organic disease, and pallor of the optic disks, absent abdominal reflexes, and extensor plantar responses are unequivocal evidence of such a condition. It is not rare, however, for a patient to develop hysterical symptoms in addition to those of such an organic disease as disseminated sclerosis.

Prognosis.

The extremely variable course renders prognosis difficult. The disease may terminate fatally in three months, or the patient may still be able to work after 25 years. When retrobulbar neuritis is the first symptom the next may not follow for many years. Among my own patients there have been remissions of 13, 15, 17, and 19 years after an attack of retrobulbar neuritis, and of 20 and 25 years after another symptom before the disease has recurred. It is conceivable that a remission may last a lifetime and the patient recover permanently from his first attack. By the time the diagnosis is made, however, there is usually ample evidence that the disease is progressive, and the only question is what its rate of progress will be. This is usually more rapid in the young than in the middle-aged and in the diffuse than in the spinal form. Implication of the brain-stem is of bad prognostic import. The average duration of life is about 10 years, in fatal cases; but in a series of 47 surviving patients the average duration was already 13·6 years, and survival for 20 years is not very rare. One of my patients was alive after 29 years.

The end is distressing. An account of it is given by a sufferer who was also a graphic writer, W. N. P. Barbellion, in *The Diary of a Disappointed Man* and *Enjoying Life*. Ataxia, weakness, and spasticity confine the patient to bed and prevent him from carrying out the simplest actions for himself. Swallowing becomes difficult and speech almost unintelligible. Urinary or cutaneous infection or pneumonia finally releases the sufferer. In rare cases the last event is an acute exacerbation of the disease itself, taking the form of an acute myelitis or encephalo-myelitis.

Treatment.

There is no specific treatment. In the absence of conclusive proof of a causal organism, vaccines and sera are still experimental. The general management of the patient requires tact and judgement. Fatigue is to be avoided, but short of this every effort should be made to keep him at his usual occupation as long as possible. In the later stages encouragement and suggestion may long postpone the bedridden state. Arsenic is by general consent the most useful drug. It may be employed intravenously as silver-salvarsan 0 2 gm.

or novarsenobillon 0·45 gm. Weekly intravenous injections may be given for four or six weeks, the course being repeated every few months. Liquor arsenicalis may be given by the mouth in courses lasting six weeks with equal intervals of rest. Potassium iodide appears to hasten the recovery from exacerbations, and may be combined with mercury given either by the mouth or by inunction as in the treatment of syphilis. Colloidal silver, antimony, urotropin, sodium salicylate, and quinine hydrochloride all have their advocates Gr. ½ of dry extract of belladonna in a pill will often relieve precipitate micturition or incontinence of urine. Liver extract given in a weekly intramuscular dose seems to benefit some patients.

Pyrexial treatment is worth a trial in cases that progress steadily and rapidly. Induced malaria has been used. A simpler method is to give 6 to 8 intravenous injections of a bacillus coli vaccine (Pyrifer) twice weekly in graduated doses. Massage and passive movements may help to relieve spasticity and re-educational exercises to control inco-ordination. In the late stages the skin, bladder, and rectum will require special attention as in paraplegia from any cause.

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6. DIFFUSE SCLEROSIS

Classification and Synonyms. See p. 470.

Definition. A group of progressive diseases usually occurring early in life and characterized pathologically by widespread demyelination of the white matter of the cerebral hemispheres, and clinically in typical cases by visual failure, mental deterioration, and spastic
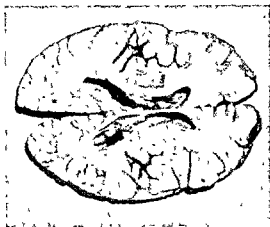
FIG. 52. Diffuse sclerosis. Note the massive and symmetrical demyelination of the white matter of the posterior two-thirds of the cerebral hemispheres.

paralysis. Both sporadic and familial cases are encountered. The aetiology of these disorders is unknown and there is no general agreement as to their classification. At present their resemblances to one another appear to outweigh their differences and they are therefore included under a common title. For a discussion of the problems involved in their classification see p. 469.

Pathology.

There is usually considerable atrophy of the brain and it may be tougher than normal. On section the white matter of the cerebral hemispheres exhibits a slightly translucent and somewhat hyaline appearance, varying in colour from grey to yellow or brown. The abnormal areas, which may be gelatinous or much firmer than normal brain, are sharply demarcated from healthy cerebral tissue, especially from the cortex, though occasionally this suffers also. The white matter of the occipital lobes is usually most severely affected (Fig. 52). The white matter of the cerebellum may be

involved as well as that of the cerebral hemispheres. Microscopically the primary change appears to be a degeneration of the myelin sheaths and later of the axis cylinders of the white matter of the affected areas. In some cases this alteration has been described as possessing a perivascular distribution at the onset. Neuroglial overgrowth is conspicuous, especially in the neighbourhood of the blood-vessels. There is a diffuse infiltration of the brain with compound granular corpuscles, and these are present in large numbers in the perivascular sheaths, which usually also contain small, round cells resembling lymphocytes.

The pathological change usually begins symmetrically in both occipital lobes and spreads forwards in the white matter of the hemispheres, ultimately involving the corpus callosum and reaching as far forwards as the frontal and temporal poles, but there are exceptions to this The frontal lobes may suffer more than the occipital, and the changes may be asymmetrical, even predominantly unilateral. Concentrically arranged rings of demyelination with relatively normal white matter between them have been described (Baló). The white matter of the internal capsules and brain-stem may be similarly involved, but the subsulcine and arcuate fibres usually escape. Involvement of the basal ganglia is inconstant. Small clear-cut areas of demyelination resembling those of disseminated sclerosis have been found in the brain-stem.

Aetiology.

The only known facts about the aetiology of the diffuse sclerosis are statistical. In half the cases the onset occurs before the age of 14 and in 40 per cent. before 10. These 40 per cent. are approximately equally divided between the first and second quinquennia. In a small number of patients the disease begins later in life, even up to old age. Males are affected more often than females in childhood, but the sexes suffer with equal frequency after adolescence. Although most reported cases have been sporadic the number of familial examples is increasing. Bielschowsky and Henneberg believe that encephalitis periaxialis diffusa (Schilder's disease) is a sporadically occurring inflammatory condition and is therefore to be distinguished from the familial and degenerative diffuse sclerosis. Many writers, however, regard these two conditions, whatever their aetiology, as allied if not identical. There is no evidence, beyond a doubtful interpretation of perivascular round cell infiltration, in favour of their inflammatory nature. The early infantile examples have been attributed to a failure of development of the myelin sheaths, later cases to a failure to maintain their nutrition. This in turn has been ascribed to a defect of the oligodendrocytes (Greenfield),

a disturbance of the power of the glial cells to regulate lipoid metabolism (Scholz), and the presence of abnormal lipoids in the blood (Bielschowsky and Henneberg). A vascular disturbance of the white matter has also been blamed. Innes has pointed out the resemblance between 'sway-back', a pre- and post-natal disease of lambs, and Schilder's disease. The cause of 'sway-back' is obscure, but it can be prevented by giving copper to the ewes. (Innes, 1939.)

Symptoms.

The onset of symptoms is sometimes rapid, sometimes insidious. Headache and giddiness may occur, but fever is exceptional. Visual impairment is one of the earliest symptoms, but may be preceded by mental deterioration, epileptiform attacks, aphasia, or weakness and inco-ordination of the limbs. Visual failure is usually due to destruction of the optic radiations. When one occipital lobe is first involved the first visual field defect is homonymous hemianopia on the opposite side, the remaining halves of the visual fields being subsequently gradually lost as the opposite occipital lobe becomes involved. In other cases both sides are involved symmetrically. In either case the end result is blindness. In other cases visual impairment is due to demyelination of the optic nerves leading to retrobulbar or optic neuritis with bilateral central scotomas. In such cases there may be papillitis during the acute stage followed by optic atrophy. Papillitis is found in about 25 per cent. of patients. Unless the optic nerves are thus involved the pupillary reactions are likely to be normal. Diplopia is not uncommon and is usually due to external rectus paralysis. *Third-nerve palsy occurs much less frequently. Nystagmus is* common. Loss of smell and taste, deafness, and tinnitus have been described.

Progressive spastic weakness of the extremities gradually develops. One side of the body may be thus affected before the other, but a spastic diplegia is the final state. Sensory loss is not uncommon and is usually of the cortical type, with loss of postural sensibility, appreciation of passive movement, and tactile discrimination, leading to astereognosis. When the internal capsules are involved analgesia involving one or both halves of the body is added. General inco-ordination is common in the early stages. Aphasia may occur, but *later tends to be masked by spastic dysarthria. Mental changes are* usually conspicuous and are those of a progressive dementia. Epileptiform attacks, which may be either generalized or Jacksonian, may occur at any stage of the disease. The cerebro-spinal fluid is usually normal, but slight mononuclear pleocytosis and increase of protein content have been described.

Diagnosis.

In a typical case the early onset of blindness unattributable to a lesion of the optic nerves, together with progressive mental failure and spastic paralysis, constitutes a highly distinctive clinical picture. When the symptoms of diffuse sclerosis are for a time predominantly unilateral and especially when papilloedema occurs, it may be confused with intracranial tumour. Encephalography may help in the diagnosis by yielding evidence of cerebral atrophy and the ultimate development in diffuse sclerosis of extensive involvement of both cerebral hemispheres will enable a tumour to be excluded. Diffuse sclerosis may also simulate disseminated sclerosis, but many cases of the former occur at an age when the latter is either unknown or very rare. Further, the severe visual impairment without involvement of the optic nerves which is characteristic of diffuse sclerosis does not occur in disseminated sclerosis, in which also epileptiform attacks are very uncommon and mental deterioration is very rarely severe.

Prognosis.

The disease is invariably progressive and almost always terminates fatally, although exceptionally temporary remissions occur, and it may possibly sometimes become arrested. It may run an acute course, leading to death within one or two months, and few patients survive more than three years after the onset of the symptoms. Very rarely life may be prolonged for a number of years.

Treatment.

The cause of the disease being unknown, treatment is empirical and none is known to arrest its course. Temporary benefit, however, has been attributed to the use of arsenic, mercury, and iodide. The usual sedatives should be employed to control the convulsions.

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CHAPTER XII

EXTRAPYRAMIDAL SYNDROMES

1. THE CORPUS STRIATUM

The Anatomy and Connexions of the Corpus Striatum

THE corpus striatum is, phylogenetically, the oldest part of the cerebrum. It lies deep in the substance of the cerebral hemisphere between the lateral ventricle and the island of Reil. It consists of the caudate nucleus and the lenticular nucleus, which is divided into the putamen and the globus pallidus (Figs. 2 and 53).

The Caudate Nucleus. The caudate nucleus is a pear-shaped mass of grey matter. Its head, the most anterior part of the corpus striatum, is on the lateral side of the anterior horn of the lateral ventricle, into which it bulges. Its tail runs backwards in the floor of the lateral ventricle, and then forwards and downwards in the roof of the descending horn.

The Putamen is separated from the island of Reil by a narrow zone of grey matter, the claustrum, and another of white matter, the external capsule.

The Globus Pallidus lies medially to the putamen. It is separated from the optic thalamus and the caudate nucleus by the internal capsule, which also separates the head of the caudate from the anterior part of the putamen.

The caudate nucleus and putamen develop from the same mass of grey matter and show the same histological structure. They contain two types of ganglion cell, a small number of large cells among more frequent small ones. The globus pallidus contains only one type of ganglion cell. On account of their common origin and identical structure the caudate and putamen are grouped together by some writers as 'the striatum', the globus pallidus being distinguished as 'the pallidum'.

The corpus striatum contains numerous fibres which may be divided into (1) afferent, (2) internuncial, and (3) efferent.

(1) Afferent fibres reach it from the cerebral cortex, from the optic thalamus, and from the midbrain. They are distributed chiefly to the caudate nucleus and putamen.

(2) Internuncial fibres unite the caudate and the putamen, and also connect these fibres with the globus pallidus. It is thought that the afferent fibres terminate in relation with the small ganglion cells, and that the fibres connecting the striatum with the pallidum originate in the large ganglion cells.

(3) Efferent fibres are derived solely from the globus pallidus which

they leave in a special bundle, the ansa lenticularis, which is distributed chiefly to the optic thalamus, the red nucleus, the substantia nigra, and the hypothalamic nucleus or corpus Luysii.

The Red Nucleus. The red nucleus lies in the tegmentum of the midbrain at the level of the superior corpora quadrigemina. In addition to fibres from the corpus striatum it receives impulses from

Caudate nucleus

Parietal stalk of thalamus
Corticospinal tract
Insula
Claustrum
Putamen
Globus pallidus

Thalamus

Ventral stalk of thalamus

Red nucleus

Ansa lenticularis
Hypothalamic nucleus
Substantia nigra
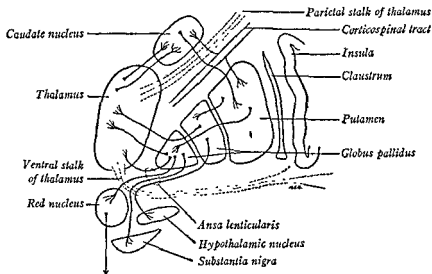
Fɪɢ. 53. Diagram of the connexions of the caudate and lenticular nuclei (*Ranson.*)

the opposite dentate nucleus of the cerebellum by the superior peduncle. It is divided into a large-celled and a small-celled portion. From the former the rubrospinal tract takes origin, and crossing the middle line in the decussation of Forel descends through the brainstem to the spinal cord. The small-celled portion gives rise to fibres which ascend to the frontal lobe.

The Substantia Nigra. The substantia nigra is a grey mass lying between the basis pedunculi and tegmentum of the midbrain at the level of the superior corpora quadrigemina. It consists of a zona compacta lying dorsally and containing large melanin-bearing ganglion cells to which it owes its dark colour, and a zona reticulata lying under this and resembling in structure the globus pallidus. Besides incoming fibres from the corpus striatum it is said to receive a direct connexion from the cortex of the frontal lobe, and it sends fibres to the red nucleus, to the hypothalamic nucleus, and to lower regions of the brain-stem.

The Hypothalamic Nucleus. The hypothalamic nucleus is a small

mass of grey matter on the dorsal aspect of the basis pedunculi, to
the lateral side of the substantia nigra. Besides receiving fibres
from the globus pallidus, it communicates with the red nucleus and
with the substantia nigra.

THE FUNCTIONS OF THE CORPUS STRIATUM

Much is still obscure about the functions of the corpus striatum,
and they are the subject of very divergent views. Almost all patho-
logical processes which injure this region of the brain are diffuse
and affect other parts as well, hence it is often doubtful whether a
given symptom is to be attributed to a striatal lesion or to a lesion
which may be present elsewhere. Moreover, many theories advanced
imply too rigid a conception of the localization of functions in the
nervous system. The fact that a lesion in a certain situation disturbs
a given function does not mean that the disordered function should
be regarded as localized in the part affected. Ultimately all neural
functions are activities of the nervous system as a whole, and in
a narrower sense, cortical, striatal, and mesencephalic centres may
be linked together in effecting and co-ordinating a movement or
a posture. Hence it is not surprising, but rather to be expected,
that similar disorders of function should be produced by lesions in
different situations. The following provisional scheme represents
what appears the most plausible conception of striatal function.

It seems probable that the functions of the striatum are sub-
ordinate to those of the cerebral cortex. There is much evidence for
the existence of direct cortico-striate fibres. Even if, with Wilson,
one denies the existence of these, an alternative route from the cortex
to the striatum lies through the optic thalamus. It is also likely
that these cortical impulses arouse the activity of the caudate and
putamen, which in turn influence other centres only through the out-
going paths of the globus pallidus. Even this structure, as far as is
known, has no direct communication with the lower motor neurones,
but exerts its influence through lower centres and their tracts, of
which the red nucleus and the rubrospinal tract are perhaps the most
important. Through the optic thalamus also the corpus striatum may
receive impulses derived from the great ascending sensory stream.

These anatomical arrangements suggest that the striatum possesses
a subordinate reinforcing rather than an initiating function, and
this view is borne out by pathological physiology. Loss of striatal
function is best exemplified by the pallidal syndrome seen in paralysis
agitans and encephalitic Parkinsonism. In this condition voluntary
and emotional movements are slow and weak, synergic muscular
contraction is feeble, and certain semi-automatic movements, such
as blinking, ocular convergence, and swinging of the arms in walking

are impaired. No doubt the associated muscular rigidity contributes to the impairment of motor function, but that it is not the primary cause is indicated by the frequent observation that the characteristic motor deficiency may precede demonstrable rigidity. Since the globus pallidus is the source of the efferent path of the striatum it is probably correct to regard the syndrome produced by pallidal destruction as striatal deficiency, and therefore to regard the corpus striatum as the seat of motor elements reinforcing and strengthening movements and postures of cortical origin, and contributing especially their automatic motor accompaniments. The part played by lesions of the corpus striatum in the production of such syndromes as chorea, athetosis, and torsion-spasm is more obscure. *Physiologically these disorders present features which are the corresponding opposite of the symptoms of Parkinsonism.* If we analyse the involuntary movements of chorea, for example, we find that they are motor activities of a high order, resembling fragmentary and disordered *forms of emotional and voluntary movement.* Moreover, associated movements, impaired or lost in the pallidal syndrome, are exaggerated in chorea. When a choreic patient is made to clench his fist his whole body partakes in movements which are an exaggerated and disorganized form of the associated movements normally accompanying great muscular effort. *The disorganization consists of a loss of reciprocal relaxation and a loss or inco-ordination of the synergic muscular contractions necessary to orderly movement.* Further, whereas rigidity is a characteristic of Parkinsonism, muscular hypotonia is present in chorea and athetosis. Hence it has been argued that whereas Parkinsonism represents a *loss of function* of the corpus striatum, chorea and athetosis are due to a *disorganization* or 'ataxia' of its activity, and are to be ascribed to lesions involving especially the caudate nucleus and putamen. It is true that in some forms of chorea and athetosis these structures undergo degeneration, for example, in Huntington's chorea and the 'athétose double' of infancy. On the other hand, the severe degenerative changes found in them in hepato-lenticular degeneration are associated with symptoms allied to Parkinsonism, and there seems no doubt that chorea may follow a lesion confined to the upper part of the midbrain. Lafora has produced it experimentally *by injuring the red nucleus and rubrothalamic tract in cats,* and Martin has described it as a sequel of lesions confined to the hypothalamic nucleus. Choreiform movements have been observed also to follow lesions of the optic thalamus. It is therefore probable that choreiform movements may result from *lesions in more than one situation, and it is possible that they depend* upon the disorganization of a path running from the cerebellum through the upper midbrain and optic thalamus and normally

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influencing the functions of the corpus striatum. Several writers
have drawn attention to the resemblance between the involuntary
movements of rheumatic chorea and the normal spontaneous move-
ments of the infant. A purely anatomico-pathological interpretation
of the chorea of childhood may be inadequate and its effect may
be temporarily to abolish recently acquired functions and to throw
the patient back to a condition akin to infancy.

We do not at present know what determines the difference be-
tween chorea, athetosis, and torsion-spasm. That these disorders
are closely allied is indicated by their possession of common physio-
logical features, and by the occurrence of intermediate forms. Their
differences may depend upon whether the striatal lesion is diffuse
or focal, and whether or not other structures are also involved. The
improvement which may follow Putnam's (1933) operation of divi-
sion of the antero-lateral column of the spinal cord in torsion-spasm,
chorea-athetosis, and athetosis suggests that these involuntary
movements are mediated by extrapyramidal fibres in the spinal cord. \

As already mentioned, disturbances of tone are prominent in cases
of striatal lesion. Parkinsonism is usually associated with rigidity,
while in chorea the muscles are hypotonic, as they are between the
spasms in athetosis and in torsion spasm. Parkinsonian rigidity is
best regarded as due to a release of lower tone-controlling centres
normally inhibited by the globus pallidus, while the hypotonia of
chorea-athetoid syndromes may be ascribed to a deficiency of the
normal contribution of the striatum itself to postural tone.

Tremor is a variable concomitant of striatal lesions, and is prob-
ably due to a loss of regulating influence of the globus pallidus upon
the rhythm of discharge of lower centres.

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2. THE PARKINSONIAN SYNDROME

Definition: The Parkinsonian syndrome, named after James Parkinson, who first described paralysis agitans in 1817, is a disturbance of motor function characterized chiefly by slowing and enfeeblement of emotional and voluntary movement, muscular rigidity, and tremor. Parkinsonism may be produced by a number of different pathological states and is usually ascribed to lesions involving the corpus striatum or the substantia nigra.

Aetiology and Pathology.

Jakob and Ramsay Hunt consider that loss of the large ganglion cells of the corpus striatum is the essential cause of Parkinsonism, though the former would place the lesion principally in the caudate nucleus and putamen, and the latter in the globus pallidus. A number of workers have claimed to demonstrate that in Parkinsonism due to encephalitis lethargica there are constant changes in the substantia nigra, but that the corpus striatum may be normal. In view of the close connexion between these two nuclei through the ansa lenticularis it is probable that they are functionally related, and it would not be surprising if lesions of both produced similar symptoms.

The histological changes depend upon the nature of the causal pathological process. Degeneration of the corpus striatum may be massive enough to lead to cavitation visible to the naked eye as in hepato-lenticular degeneration. Focal degeneration due to vascular occlusion is the basis of Parkinsonism due to cerebral arteriosclerosis. Paralysis agitans is probably due to a primary senile or presenile cellular degeneration of the large ganglion cells of the striatum, and a similar degeneration in the 'pallidal system' has been held by Ramsay Hunt responsible for a juvenile form of the disorder. The Vogts regard the lesion characteristic of paralysis agitans as an *état de désintégration* of the corpus striatum, ranging from a disappearance of ganglion cells and fibres to the formation of areas of softening with the production of cavities, *état lacunaire*. Uncommon toxic causes of Parkinsonism are poisoning with carbon monoxide and with manganese. In encephalitic Parkinsonism there is great

destruction of the pigment-bearing cells of the substantia nigra, the
pigment lying free in the parenchyma. There is glial reaction, and
the presence of lymphocytes, especially in the perivascular sheaths,
is taken to indicate that the infection is still active. Rarely Parkin-
sonism follows head injury, when it is probably due to haemorrhage
into the corpus striatum or substantia nigra, and it has been observed
to follow injury to a limb, the symptoms beginning in the injured
limb. *It is occasionally due to neurosyphilis.*

Symptoms.

*A general description of the symptoms of the Parkinsonian syn-
drome* will first be given, and the distinctive features of the various
forms of the disorder will then be considered separately.

Facies and Attitude.

The Parkinsonian facies is characteristic. The palpebral fissures
are usually wider than normal, and blinking is infrequent. The eyes
have a staring appearance, due partly to these features and partly
to the fact that spontaneous ocular movements are lacking or seldom
occur. The facial muscles exhibit an unnatural immobility (Fig. 54).
The mouth is often slightly open, and saliva, which appears to be
secreted in excess, may run from the lower lip. The skin of the face
is often exceptionally greasy. The attitude of the limbs and trunk
is one of moderate flexion. The spine is usually somewhat flexed,
but *is occasionally extended*. There *is little rotatory movement* of
the cervical spine. The limbs are moderately flexed and adducted,
but the wrist *is usually* slightly extended. The fingers are flexed at
the metacarpo-phalangeal, and extended or only slightly flexed at
the interphalangeal, joints, and adducted. The thumb is usually
adducted, and extended at the metacarpo- and inter-phalangeal
joints.

Disorders of Movement.

Voluntary movement exhibits some impairment of power, but
more striking is the slowness with which it is performed. In general
the movements which are carried out by small muscles suffer most.
Hence the patient shows, weakness of the ocular movements, espe-
cially convergence; of the facial movements, associated with tremor
of the eyelids on closure of the eyes; and of movements concerned
in mastication, deglutition, and articulation. The speech in severe
cases is slurred and monotonous, owing to defective pronunciation
of consonants and lack of variation in pitch. Rarely palilalia occurs.
Movements of the small muscles of the hands are also markedly
affected, with resulting clumsiness and inability to perform fine

movements, such as those used in needlework, dealing cards, and taking money from a pocket. Micrographia is common. Certain associated and synergic movements suffer conspicuously. Swinging of the arms in walking is early diminished and later lost, and the

Fig. 54. A case of paralysis agitans. (Note the expressionless facies and the attitude of the hands.)

synergic extension of the wrist, which is normally associated with flexion of the fingers, is also impaired. Thoracic expansion in inspiration is reduced, but the contraction of the diaphragm may be increased in compensation.

Emotional movements of the face are also reduced in amplitude, slow in developing, and unduly protracted.

Muscular Rigidity.

Muscular rigidity does not always develop *pari passu* with the disorders of movement just described, which not uncommonly

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somewhat precede it. It differs from the hypertonia associated with pyramidal lesions in that it is present to an equal extent in opposing muscle-groups, for example, the flexors and extensors at the elbow; it is uniform throughout the whole angle of movement at a joint; and it usually exhibits an interrupted character when tested by passive movement, the muscles yielding to tension in a series of jerks, hence the term 'cog-wheel rigidity'. Parkinsonian rigidity, like other Parkinsonian symptoms, is often unequal on the two sides of the body. In spite of the rigidity full passive movement is usually possible at all joints. Occasionally, however, contractures occur which limit such movement. This happens most frequently in the hands and the feet. The fingers may be so strongly flexed that a pad has to be used to prevent the nails being driven into the palm. Similar flexor deformity of the toes may occur, and talipes equino-varus may be produced

Gait.

The Parkinsonian gait is in part at least the outcome of the patient's attitude and rigidity. It is usually slow, shuffling, and composed of small steps. The patient is often unable to stop quickly when pushed forwards or backwards—propulsion and retropulsion. When propulsion occurs spontaneously during walking the patient exhibits a 'festinating' gait, hurrying with small steps in a bent attitude as if trying to catch up his centre of gravity. A striking feature of Parkinsonism is the frequent ability of the patient to carry out rapid movements requiring considerable exertion better than slower and less energetic movements. Thus a patient who can only walk very slowly may be able to run quite fast. This phenomenon has been called 'kinesia paradoxa'.

Tremor.

Tremor is the characteristic involuntary movement of Parkinsonism. Tremor, rigidity, and slowness and weakness of movement are, however, to a large extent independent variables. Tremor may be the first symptom, as it frequently is in paralysis agitans, and may precede rigidity by months or years. In encephalitic Parkinsonism rigidity more often precedes tremor. Tremor usually begins in one upper limb and later involves the lower limb on the same side, the other side being affected in the same order after a further interval. The head is involved late, if at all.

The tremor consists of rhythmic alternating movements of opposing muscle-groups. In the upper limb the hand is most affected. Movements of the fingers occur at the metacarpo-phalangeal joints and may be combined with movements of the thumb—the 'pill-

rolling movement'. Movements at the wrist may be flexion and extension, lateral displacement, or pronation and supination. Often the tremor shifts from one to another group of muscles while the patient is under observation. Little movement usually occurs at the joints above the wrist. In the lower limb tremor is most marked at the ankle, at which flexion and extension occur. Either flexion and extension or a rotatory tremor of the head may occur. When the mandibular muscles are involved rhythmical opening and closure of the mouth are observed, and in the tongue the tremor takes the form of protrusion and withdrawal.

The rate of the tremor lies between four and eight movements a second. It is present when the patient is at rest, and is often temporarily suppressed when the limb is voluntarily moved. Rarely, however, it is increased by movement. It can often be inhibited for a time by conscious effort, but is liable to break from this control with increased intensity. It is increased by emotional excitement and almost always disappears during sleep.

Sensory Symptoms.

There is no loss of sensibility in Parkinsonism. Pain, however, is common, especially in the later stages, when most patients complain of cramp-like pains in the limbs and spine due to the muscular rigidity and the changes induced in the joints and ligaments by the abnormal posture. Extreme restlessness is also a common symptom, the patient suffering great discomfort unless his position is changed every few minutes.

The Reflexes

Parkinsonism does not involve any essential changes in the reflexes, though rigidity may render the tendon jerks difficult to elicit and reduced in amplitude. The plantar reflexes are flexor unless an independent lesion involves the pyramidal tracts.

Autonomic Symptoms

Derangement of the autonomic nervous system is probably responsible for a group of symptoms which often cause much discomfort. Excess of sebaceous secretion over the face and excessive salivation have already been mentioned. Flushing of the skin may occur, accompanied by uncomfortable sensations of heat and sometimes by sweating. These symptoms may be limited to, or more marked upon, one side of the body. Oedema and cyanosis of a limb are rare. Parkinsonian patients usually tolerate cold much better than heat, and will often sit out of doors, lightly clad, in the coldest weather without feeling cold.

Mental State.

Parkinsonism is not necessarily accompanied by any mental change, and the sufferer's intellectual capacity and emotional re-actions may continue unimpaired behind the mask in which his disorder fixes his features. But when the syndrome is a manifestation of a diffuse pathological process, such as cerebral arteriosclerosis or encephalitis lethargica, involvement of other parts of the brain may cause associated mental deterioration, leading to various degrees of dementia, or a loss of emotional responsiveness, or profound depres-sion with a suicidal tendency.

FORMS OF PARKINSONISM

PARALYSIS AGITANS

Synonyms: Parkinson's disease; shaking palsy.

Pathology.

See p 511.

Aetiology.

The disease is probably a primary degeneration of the large ganglion cells of the corpus striatum, and *it is doubtful* whether external factors have any aetiological significance, though there is some evidence that injury to a limb may determine the site of onset of the symptoms. Males are affected about twice as frequently as females Paralysis agitans is a disease of late middle life and begins in most cases between the ages of 50 and 60. In women its onset not uncommonly occurs within a year or two of the menopause and in men at about 60. It rarely begins before 40 and after 65, but in the rare juvenile form the onset may be as early as the second decade (Hunt). It is exceptionally hereditary or familial.

Symptoms.

In the majority of cases tremor is the first symptom. Less fre-quently weakness, stiffness, and slowness of movements are com-plained of before tremor. The tremor usually begins in one hand, the leg on the same side being next involved. After a further interval it spreads to the opposite hand and later to the opposite leg. It may be confined to one side of the body for several years, but both upper limbs may be affected before the lower limbs. The characteristics of the tremor, rigidity, and other symptoms have already been described.

Prognosis.

The disease is always progressive, though cases differ considerably in the rate of progress. The symptoms may be confined to one limb

for months or years, and the spread to other limbs when it occurs may be slow or fairly rapid The development of rigidity may diminish the tremor, but greatly reduces the patient's activities. Even so he may survive in a helpless condition for many years The average duration of the disease is about ten years, but it is not uncommon for patients to live considerably longer Death occurs usually from complications such as pneumonia or bed-sores Occasionally there is a terminal stage of lethargy passing into coma

Parkinsonism following Encephalitis Lethargica

Pathology.

See pp 429 and 511.

Aetiology.

See pp 429 and 511.

Symptoms.

It is not uncommon to observe some Parkinsonian symptoms in the acute attack of encephalitis In most cases Parkinsonism develops insidiously during the subsequent twelve months, though the interval may be as long as twenty years There may be no history of an acute attack obtainable. Since the greatest incidence of the disease is in early adult life, most cases of encephalitic Parkinsonism occur before the age of 40.

Stiffness, slowness of movement, and weakness usually precede tremor. These symptoms are usually more marked upon, and may be confined to, one side of the body Sometimes they are even more restricted and involve only one upper limb, or one upper limb and the same side of the face. In the early stages the upper limb is usually more affected than the lower Rigidity is usually more conspicuous than tremor throughout the course of the illness The pupillary reactions to accommodation or to light or to both are usually impaired, and mental apathy or depression is usually conspicuous (see p. 433).

Oculogyral Spasm.

Spasm of conjugate ocular muscles is a not infrequent complication of Parkinsonism following encephalitis lethargica The attacks last from a few seconds to hours The eyes are usually deviated upwards, with lids retracted, less often laterally, and rarely downwards or obliquely There may be an associated spasmodic deviation of the head in the same direction. Occasionally the eyes become fixed when the gaze is directed forwards, or in a position of convergence.

Emotion may precipitate the attacks, which are often accompanied by feelings of anxiety or by abnormal sensations referred to the head. During the attack the patient's attempts to overcome the eyes in other directions result in only a very feeble, jerky displacement from the position of spasmodic deviation. There is no reason to regard oculogyric crises as psychogenic in origin. They are probably disturbances of the regulation of ocular posture at the level of the supranuclear centres immediately above the midbrain.

Prognosis.

In most cases Parkinsonism following encephalitis is a progressive condition running a much shorter course than paralysis agitans. In a few cases the disorder seems to become arrested and this happens most often when the symptoms are predominantly unilateral. In severe cases the patient may become quite incapacitated within a year of the onset of symptoms, but at present milder chronic cases are the rule and the disorder often reaches a stationary condition. Death is due to pneumonia, bed-sores, or a general cachexia terminating in coma.

ARTERIOSCLEROTIC PARKINSONISM

Parkinsonian symptoms may make their appearance in the course of cerebral arteriosclerosis, but the resulting clinical picture is not only very variable in itself but also frequently complicated by the presence of other symptoms of vascular lesions. Thus Parkinsonism may exist alone, or in association with pseudo-bulbar palsy, pyramidal lesions, or dementia.

The majority of cases are due to the decrescent type of arteriosclerosis with low blood-pressure, and are, therefore, found in late middle and old age. The age-incidence is, therefore, later than that of paralysis agitans, though vascular lesions resulting from hyperpiesia may produce the syndrome earlier in life. The onset is usually insidious, but in some cases follows a 'stroke'; and a series of mild 'strokes' may each be followed by an increase in the severity of the symptoms.

Of the true Parkinsonian symptoms, the expressionless facies, bodily attitude, slowness and weakness of movement, and the festinating gait are the commonest. The rigidity is often atypical, being variable in degree and predominating in the flexors of the elbows and in the extensors of the knees. Parkinsonian tremor is rare in these cases, though senile tremor may occur. Catatonia is not uncommon. It seems probable that the symptoms are in part due to lesions at a higher level than the corpus striatum, interrupting cortico-striate fibres.

The course of the disorder is more rapid than that of paralysis agitans. When the blood-pressure is high, a fatal cerebral haemorrhage may occur. When the decrescent form of arteriosclerosis is the cause, dysphagia, contractures, and incontinence render nursing difficult, and the patient *succumbs in a few years* Dementia further reduces the expectation of life

The Diagnosis of Parkinsonism.

It is necessary (1) to distinguish the Parkinsonian syndrome from other conditions which may simulate it, and (2) to discriminate the various pathological states which may be responsible for it. The *most striking Parkinsonian symptoms being tremor and muscular rigidity*, Parkinsonism is most likely to be confused with conditions causing one or other of these symptoms

Other Causes of Tremor.

Senile Tremor. Tremor is not uncommon in old age It differs from Parkinsonian tremor in being finer and more rapid At first it is absent when the limbs are at rest and occurs only on voluntary movement. Later it may be present during rest also It is most marked in the upper limbs, but is more frequently present in the head than Parkinsonian tremor It is not associated *with muscular* weakness or rigidity.

Familial Tremor. There is a form of tremor which may occur in several members of the same family, sometimes in successive generations It may begin in infancy and usually develops during the first twenty-five years of life It is a fine tremor, increased by voluntary movement and emotion, and may be generalized or involve especially the hands, lips, and tongue As a rule it persists unchanged throughout life and no other nervous abnormality occurs In rare instances paralysis agitans has been observed in a member of a family afflicted with familial tremor.

Hysterical Tremor. Two forms of hysterical tremor are encountered: a fine tremor, localized to one limb or generalized, and resembling the shaking of extreme fear, of which it *is probably* a perpetuation; and a coarse, irregular shaking, intensified by voluntary movement. In common with other hysterical symptoms, *hysterical tremor is characterized by its irregularity, variability* from time to time, and by a tendency to diminish when the patient's attention is distracted and increase when it is directed to the affected part of the body.

Tremor in Hyperthyroidism. This is a fine, rapid tremor usually confined to the outstretched arms and sometimes more marked on one side than the other. The associated exophthalmos, thyroid

enlargement, tachycardia, and flushed and sweating skin render diagnosis easy.

Toxic Tremor. Tremor may be a symptom of intoxication with various poisons, especially mercury, cocaine, and alcohol. The tremor of cocaine addiction and chronic alcoholism is fine and is unlikely to be confused with Parkinsonian tremor. The tremor of chronic mercurial poisoning and delirium tremens is somewhat coarser, but has not the rhythmical character of Parkinsonian tremor. In all these cases the cause is usually easily discoverable, and in delirium tremens the acute onset and characteristic mental symptoms are distinctive.

Disseminated Sclerosis. In disseminated sclerosis intention tremor is common. It is absent when the limb is at rest and develops only during voluntary movement, increasing as the limb approaches its objective. In this respect it is the opposite of Parkinsonian tremor, which is present at rest and often diminishes on movement. Static tremor is rarer in disseminated sclerosis, and is most often seen in the head. It disappears when the patient is lying with the neck muscles relaxed. In this disease there are usually nystagmus and signs of pyramidal lesions, which, apart from the character of the tremor, distinguish it from Parkinsonism.

General Paralysis. Tremor affecting especially the face, tongue, and hands is an early symptom of general paralysis. This is a fine tremor, increased on voluntary movement. The mental changes, Argyll Robertson pupils, signs of pyramidal lesions, and positive Wassermann reaction in the blood and spinal fluid will distinguish the condition from Parkinsonism.

Other States of Rigidity.

Catatonia. Catatonia is a state in which the patient spontaneously becomes immobilized in a fixed attitude which may persist for hours. Sometimes an attitude passively imposed by the observer is similarly maintained—waxy flexibility. Catatonia appears to be a symptom of disorder of function of the frontal lobes. In the limbs it may be unilateral or bilateral. It is encountered in individuals suffering from tumours, vascular lesions, inflammatory and degenerative states involving the frontal lobes, in psychoses, especially schizophrenia (dementia praecox), and in hysteria, and it can be produced by hypnotic suggestion. Apart from facial immobility the attitude in catatonia does not resemble that of Parkinsonism. In schizophrenia and in hysteria it is frequently associated with mutism, and in organic disease with other symptoms of a frontal lobe lesion. Waxy flexibility is not a symptom of Parkinsonism.

Hysterical Rigidity is characterized by the fact that the degree

of the rigidity is proportional to the observer's efforts to move the limb. In Parkinsonism the rigidity is, by contrast, a definite quantum which always yields to the exercise of slightly greater force.

Spasticity due to Pyramidal Lesions is distinguished by the selective distribution of the rigidity to certain muscle-groups, usually the flexors in the upper and the extensors in the lower limbs. Moreover, it tends to be maximal at the beginning of a passive movement and to diminish as the movement proceeds. Parkinsonian rigidity is uniform both in its distribution and throughout the angle of joint movement. In paraplegia-in-flexion hypertonia occurs in the flexors of the lower limbs, but in this condition, as in paraplegia-in-extension, the plantar reflexes are extensor, whereas they are flexor in uncomplicated Parkinsonism

Multiple Arthritis. Rigidity due to joint disease occasionally simulates Parkinsonism, especially when the vertebral joints are affected. The flexion of the spine and immobility of the head may at first glance be deceptive Pain in such cases, however, is always severe at some stage of the disease, and it is easy to demonstrate that the rigidity is bony and not muscular in origin.

Diagnosis of the Cause of Parkinsonism.

The diagnosis of the cause of Parkinsonism is based upon the recognition of the distinctive clinical features of the various underlying pathological states, and as these have already been described in full, they will now only be summarized

Paralysis Agitans The onset usually occurs between the ages of 50 and 60, and there is no history of a previous attack of encephalitis The pupillary reactions are normal. Tremor is usually prominent from the beginning. Progress of the disorder is slow, and the patient usually survives for a number of years.

Parkinsonism following Encephalitis Lethargica The onset usually occurs before the age of 40 There is sometimes, but of recent years not often, a history of an acute attack of encephalitis lethargica characterized by headache, disturbance of sleep rhythm, and visual impairment or diplopia. *The pupillary reactions are often impaired*, especially that to accommodation. Rigidity usually precedes tremor, which is sometimes inconspicuous throughout the illness The course of the disorder is usually more rapidly progressive than that of paralysis agitans.

Arteriosclerotic Parkinsonism. This usually develops after the age of 60 and signs of general arteriosclerosis are conspicuous Though often insidious, the onset sometimes follows a 'stroke'. The Parkinsonian clinical picture is often incomplete and tremor is rare. Other

signs of cerebral arteriosclerosis, especially pyramidal lesions, are
frequently present.

Traumatic Parkinsonism is readily distinguished by the history of
head injury, *syphilitic Parkinsonism*, by serological tests; *Parkinsonism due to manganese poisoning*, by the history of industrial
exposure to the metal and the associated hepatic cirrhosis and
hepato-lenticular degeneration by the familial incidence, early onset,
and associated hepatic cirrhosis.

Treatment.

Though the treatment of Parkinsonism is palliative rather than
curative, much can be done to relieve the patient's discomfort. The
cause of paralysis agitans is unknown, but its frequent onset shortly
after the menopause in women suggests that loss of secretion of the
gonads may be a predisposing factor. The administration of ovarian
follicular hormone to women thus possesses a rational basis. By
analogy, ligature of the vas deferens has been carried out in men and
testicular extract has been administered.

The sufferer from Parkinsonism should be encouraged to lead an
active life as long as possible. Massage and passive movements are
valuable for their temporary effect in diminishing the rigidity, but
more as a means of postponing the development of contractures.
The only drugs which influence the rigidity are those of the belladonna group, and these also diminish salivation and sweating, which
are sometimes troublesome symptoms. Hyoscine hydrobromide may
be given in doses of from 1/200th to 1/50th of a grain twice or thrice
times a day, tincture of belladonna in doses of from 5 to 15 minims,
and tincture of stramonium in doses of from 10 to 60 minims thrice
daily. Atropine sulphate may be given in 0 5 per cent. solution
beginning with 1 minim thrice a day and gradually increasing
the dose till no further benefit occurs. Excellent results have recently
been claimed for a decoction of Bulgarian belladonna root. An
extract of this (Homburg 680) is given in the same doses as atropine.
With all these drugs 1/6th of a grain of pilocarpine may be given
twice a day to diminish side-effects which may include slight delirium,
dimness of vision, owing to dilatation of the pupils and paresis of
accommodation, dryness of the mouth, and gastro-intestinal disturbances. Dimness of vision may be controlled by the instillation of
a drop of ¼ per cent. of eserine into each eye, daily or on alternate
days. Tremor is most difficult to control. Bulbocapnine, though it
diminishes tremor, has unpleasant effects and has not come into
general use. Benzedrine is sometimes of value in diminishing the
rigidity and oculo-gyric spasms and improving the mental state.
Doses ranging from 5 to 60 mg. of the sulphate daily have been given.

Tremor may be temporarily diminished by a drive in a motor-car. Aspirin, bromide, and phenobarbital may be required for the relief of pain, restlessness, and insomnia. When the patient becomes bedridden much care will be needed to prevent the development of bed-sores.

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3. HEPATO-LENTICULAR DEGENERATION

Synonyms: Tetanoid chorea (Gowers), pseudo-sclerosis (Westphal); progressive lenticular degeneration, Wilson's disease.

Definition: A progressive disease of early life which is frequently familial and is characterized pathologically by degeneration of certain regions of the brain, especially the corpus striatum, and

cirrhosis of the liver, and clinically by increasing muscular rigidity
and tremor Although pseudo-sclerosis, which was first investigated
by Alzheimer, Westphal, and others between 1883 and 1898, and
progressive lenticular degeneration, described by Wilson in 1912,
were at one time thought to be different diseases and are still so
regarded by some authorities, they are now more usually considered
to be identical and are both included under the title hepato-lenticular
degeneration. Since both lenticular degeneration and cirrhosis of the
liver were found in Thomalla's and Wimmer's cases of torsion spasm,
it appears that some examples of this disorder are varieties of hepato-
lenticular degeneration.

Pathology.

The pathological change in the nervous system consists of a
degeneration of ganglion cells with neuroglial overgrowth, but with-
out evidence of inflammation or vascular abnormality. This change
is most marked in the putamen of the lenticular nucleus. The
caudate nucleus is usually similarly affected, though to a less extent,
but the globus pallidus is less frequently involved. Similar altera-
tions are often present in other parts of the nervous system; for
example, in the cerebral cortex, the optic thalamus, the red nucleus,
and the cerebellum. Macroscopically the most conspicuous abnor-
mality is found in the lenticular nucleus. In about half the recorded
cases visible softening and cavitation of both lenticular nuclei have
been observed. In other cases the nucleus has appeared shrunken
and occasionally its naked-eye appearance is normal.

In the liver the changes are those of a multi-lobular cirrhosis
which possesses no distinctive characteristics and is often associated
with enlargement of the spleen.

Aetiology.

The cause of the disorder is obscure. There is evidence that in
some cases at least the destruction of the liver precedes the degenera-
tion of the brain. It is unlikely, however, that the former is in itself
the cause of the latter, as ordinary portal cirrhosis of the liver does
not lead to cerebral degeneration.

The most plausible hypothesis is that both conditions are produced
by a toxin which is absorbed from the alimentary canal and which,
having damaged the liver, is able in consequence to obtain access
to the general circulation. In this connexion it is interesting that
manganese poisoning produces both cirrhosis of the liver and de-
generative changes in the caudate nucleus and putamen.

In about half the recorded cases hepato-lenticular degeneration
is a familial disease, and in two unverified cases it has appeared in

more than one generation. In the present state of our knowledge its familial character might equally well be due to the exposure of members of a family to the same environment as to their participation in a common inheritance.

It is a disease of adolescence and early adult life, usually beginning between the ages of 10 and 25 years.

Symptoms.

Nervous Symptoms.

In most cases tremor is the first symptom, occurring when the limbs are at rest and increased by voluntary movement. Athetoid and writhing movements of the trunk and limbs have, however, been observed, and one patient in the terminal stage exhibited violent muscular spasms resembling tetanus.

Rigidity soon develops and is present in all cases. In distribution and general character it resembles the rigidity of Parkinsonism The limbs become fixed, usually in a position of flexion, and contractures ultimately develop.

Voluntary movement is impaired, and articulation and deglutition are early and severely affected Speech may become unintelligible *or the patient may even lose entirely the power of articulation* The facies exhibits, as in Parkinsonism, a vacant, expressionless appearance, or a vacuous smile Loss of emotional control is usually present *and involuntary laughing and crying may occur. There seems always* to be some degree of mental deterioration amounting to a mild dementia. There is no essential change in the tendon-jerks or the abdominal reflexes, though muscular *rigidity* may render them difficult to elicit. The plantar reflexes are flexor and there is no disturbance of sensibility.

Corneal Pigmentation.

Corneal pigmentation was first observed by Kayser and Fleischer. Although it has been described in only a proportion of cases, it is present with sufficient frequency to render it of diagnostic value It may be invisible in daylight and is best seen with the slit lamp and corneal microscope. It consists of a zone of golden-brown granular pigmentation about 2 mm. in diameter on the posterior surface of the cornea towards the limbus. It may be present before any nervous symptoms have developed.

Symptoms of Cirrhosis of the Liver.

Although these may be inconspicuous, in more than one case they have proved fatal before the patient developed any nervous symptoms. In the early stages pyrexial attacks, with slight jaundice,

may occur; later the liver may be enlarged and ascites, haematemesis, and other symptoms of portal obstruction may be present.

Tests of liver function usually reveal no abnormality, even in advanced cases.

Diagnosis.

There are few disorders with which hepato-lenticular degeneration is likely to be confused. No other disease is characterized by the familial occurrence of tremor and rigidity in the second decade of life. Corneal pigmentation and symptoms of cirrhosis of the liver, when present, are pathognomonic. Sporadic cases may simulate other disorders in which the corpus striatum is damaged. Double athetosis, which is characterized by muscular rigidity and choreo-athetoid movements, is usually congenital. Symptoms are therefore present from an early age, and improvement tends to occur. Encephalitis lethargica sometimes leads in childhood to symptoms which closely resemble those of hepato-lenticular degeneration. A history of an acute attack of encephalitis, when obtainable, will distinguish the former

When hepato-lenticular degeneration is suspected in one member of a family, all the siblings should be examined for evidence of nervous abnormalities, cirrhosis of the liver, and corneal pigmentation Any of these symptoms, if present, not only will render it possible to anticipate the development of the disorder in other members of the family but will afford support for the diagnosis in the patient already affected.

Prognosis.

The course of the disease may be acute, subacute, or chronic, but it is invariably fatal. In the shortest illness on record death occurred five weeks after the onset of symptoms. Fifty per cent. of patients die in from one to six years. It is now recognized, however, that the duration of the disorder may sometimes be longer than was at one time supposed, and Hall has collected from the literature 11 cases in which the patients survived from fourteen to thirty years.

Treatment.

Treatment is purely symptomatic and should be carried out on the same lines as for Parkinsonism. No method of retarding the course of the disease is known.

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4. TORSION DYSTONIA

Synonym: Dystonia musculorum deformans (Oppenheim).

Definition: A syndrome characterized by involuntary movements producing torsion of the limbs and the vertebral column, which may occur as a symptom of more than one pathological state.

Aetiology and Pathology.

Torsion dystonia is a rare syndrome which was first described by Schwalbe in 1908 in three siblings. Mendel in 1919 collected 30 cases from the literature. It is frequently, though not invariably, familial, and appears to be particularly prevalent among Russian Jews Pathological investigations have been carried out in few cases. In Thomalla's and Wimmer's cases cirrhosis of the liver was found, together with degenerative changes in the lenticular nuclei, while in addition in Thomalla's case similar changes were found in the corpus Luysii and in Wimmer's case in the thalamus, hypothalamus, and dentate nucleus of the cerebellum. On the other hand, Lévy and Wimmer have shown that torsion dystonia may occur as a sequel of encephalitis lethargica It is evidently a syndrome which may be produced by a variety of disorders, the familial examples being probably due to a cerebral degeneration allied to, if not identical with, hepato-lenticular degeneration.

Symptoms.

In the familial cases the onset usually occurs in childhood or adolescence, and the abnormality is frequently first noticed when the patient walks. In Schwalbe's family the disorder began with spasmodic plantar flexion of the feet, rendering it impossible to place the heel on the ground. The involuntary movements in the upper limbs consist of rotation or torsion round the long axes and are associated

with similar torsion movements of the vertebral column, especially in the lumbar region (Fig. 37). There are frequently lordosis and scoliosis, which are conspicuous when the patient walks, but tend to disappear when he lies down. Other forms of involuntary movement, such as tremor and myoclonic muscular contractions, have been described. Muscular tone is variable, being exaggerated during

Fig 55. A case of torsion dystonia.

the spasms and sometimes diminished in the intervals between them. Signs of a lesion of the pyramidal tracts are absent. There is no muscular wasting. The reflexes are normal, and sensibility is unimpaired. Psychical changes are absent, and speech is usually unaffected. Corneal pigmentation has not been described.

Diagnosis.

Torsion dystonia must be distinguished from other forms of involuntary movement, especially from athetosis and from chorea. In athetosis the movements, which are of a slow, writhing character, involve the peripheral parts of the limbs, rather than the

proximal as in torsion spasm. Double athetosis, moreover, is usually congenital, and hence the movements develop at an earlier age than torsion spasm. Choreic movements, like athetosis, involve the peripheral parts of the limbs to a greater extent than torsion dystonia. In chorea, however, movements of rotation of the limbs and trunk occur, but they are quicker and briefer than the corresponding movements of torsion spasm. Hysteria may cause bizarre involuntary movements resembling torsion dystonia, and Schwalbe considered that the movements in his patients were neurotic. Hysterical involuntary movements, however, rarely involve the trunk and the proximal parts of the limbs, and in hysteria the emotional attitude of the patient to the disorder and the presence of other hysterical symptoms usually settle the diagnosis.

Prognosis.

In view of the probability that torsion dystonia is a symptom of a number of disorders, no generalization can be made concerning its prognosis. In some cases recovery has been described. Others remain stationary. In some of the fatal cases the disorder has run a course similar to that of hepato-lenticular degeneration.

Treatment.

An attempt should be made to ameliorate the involuntary movements by means of rest and re-educational exercises. Sedative drugs, such as the bromides, chloral and phenobarbital may also help to diminish their severity, and drugs of the belladonna group may be tried as for Parkinsonism. In severe cases Putnam's (1933) operation of antero-lateral chordotomy may greatly improve the patient's control over the limbs.

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5. SPASMODIC TORTICOLLIS

Synonym: Wry neck

Definition: A rotated attitude of the head, brought about by clonic or tonic contraction of the cervical muscles and occurring as a symptom both of organic disease of the nervous system and of hysteria. Torticollis of organic origin is a fragmentary form of torsion-spasm. Retrocollis is a similar disorder, in which the neck is extended.

Aetiology and Pathology.

In the past, confusion as to the nature of torticollis has arisen from a failure to distinguish hysterical torticollis from torticollis occurring as a symptom of organic disease. Since torticollis can be effected voluntarily, it may occur as an hysterical symptom, being then a form of tic. The hysterical nature of the symptoms in such cases is proved by the fact that it is often possible to discover and remove its cause by psychological methods. There is abundant evidence, however, that torticollis may occur as a result of organic disease of the nervous system, and in such cases there are grounds for regarding it as a limited form of torsion spasm. It may occur as a sequel to encephalitis lethargica, with or without Parkinsonism, or as a part of other extrapyramidal syndromes. Since torticollis as an isolated symptom is not fatal, pathological investigations are scanty. Cassirer, however, has reported a case in which degenerative changes were present in the corpus striatum and were associated with cirrhosis of the liver and Foerster (1933) one in which bilateral focal lesions of the corpus striatum were present. Physiologically, torticollis is a disturbance of the normal posture of the head. The rotated posture of the head which follows unilateral labyrinthectomy and lesions of the eighth nerve indicates the importance of the labyrinth in the maintenance of the posture of the head, and torticollis is probably due to a lesion involving the higher centres concerned in this function, most frequently in the neighbourhood of the corpus striatum. Both sexes are affected, and the onset usually occurs during adult life. The disorder may be familial.

Symptoms.

The development of torticollis is usually insidious but may be sudden, especially when it is a symptom of hysteria. The rotation of the head is brought about by contraction of the cervical muscles, and though both the superficial and deep muscles of the neck are involved, the muscular contraction is evident to the observer only in the sternomastoid, trapezius, and splenius. The precise posture of the head varies in different cases. Contraction of the sternomastoid alone causes rotation to the opposite side, with flexion of the neck to the side of the contracted muscle. Rotation, however, may occur without lateral flexion, or the head may be flexed to the side to which it is rotated, in such cases contraction of the sternomastoid on one side being associated with contraction of the splenius and trapezius on the opposite side. The disturbance may be predominantly tonic, leading to a sustained posture, or may consist of repeated clonic jerks, as is particularly common in hysterical cases.

It may be possible to modify the abnormal posture by altering the position of the patient in relation to gravity, for example, from the erect to the supine, or from the supine to the prone position. There may or may not be resistance to passive movement of the head in the direction *opposite* to the abnormal position. In *a few cases* torticollis has been associated with paralysis of rotation to the opposite side. There may be spasm of the facial muscles and platysma on the side to which the head is rotated, or spasmodic torsion movements of the upper limb or of the whole body. The patient not infrequently finds that *he can inhibit the torticollis by exerting slight pressure* with his finger upon the jaw on the side to which the head is rotated, and the movement ceases during sleep. Pain may occur in the cervical muscles. The reflexes and sensation are normal.

Retrocollis is due to a bilateral contraction of the splenius and trapezius.

Diagnosis.

The distinction between hysterical torticollis and torticollis of organic origin may be difficult. Hysteria should be suspected when the symptom develops suddenly in circumstances of mental stress, and also when it can be controlled by relaxation and suggestion. A complete examination of the nervous system must be made to exclude signs of organic nervous disease.

Spasmodic torticollis is distinguished by the age of onset from congenital torticollis, which may be due either to fibrosis of one sternomastoid following a haematoma in the muscle, or to a congenital deficiency of one-half of a cervical vertebra. It is necessary also to exclude as causes of torticollis myositis of the cervical muscles, caries of the cervical spine, adenitis of the cervical lymph nodes, and impaired ocular muscle balance.

Prognosis.

Torticollis is almost always an intractable disorder, but when it is due to hysteria great improvement and even cure may be effected by psychotherapy. Sufficiently radical surgical treatment has given good results in a considerable proportion of cases of organic origin, though the spasm may recur after operation.

Treatment.

Hysterical torticollis should be treated by psychotherapy along the same lines as other hysterical symptoms, and the patient should be taught to practise muscular relaxation. Sedative drugs, massage, and galvanism are useful accessory methods of treatment. Torticollis of organic origin is unlikely to respond to medical measures.

Surgical treatment, therefore, should not be too long delayed. A number of operations have been recommended. Finney and Hughson divide the spinal accessory nerves and the posterior divisions of the upper three or four cervical nerves at their points of emergence from the vertebrae. Dandy combines division of the spinal accessory nerves with interruption of the upper three cervical sensory and motor roots within the spinal canal, and Foerster performs intradural section of both the anterior and posterior roots of the upper three cervical segments.

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6 ATHETOSIS

Definition: Athetosis, or 'mobile spasm', is the term applied to a form of involuntary movement which in some respects resembles chorea, as is recognized by the use of the term 'choreo-athetosis' to describe an intermediate condition. Athetoid movements, however, are slower, coarser, and more writhing than choreic movements. Athetosis is due to a variety of pathological states which damage the basal ganglia.

Aetiology and Pathology.

The same difficulties are encountered in localizing the lesion responsible for athetosis as in the case of chorea. Nevertheless, there is considerable evidence that it is usually situated in the corpus striatum

Bilateral Athetosis.

Bilateral athetosis may be congenital, when it may be due to the *état marbré* of the corpus striatum described by Oppenheim and C. Vogt (see p. 546), or to the involvement of this part of the brain in atrophic sclerosis, when symptoms of pyramidal degeneration may co-exist with the involuntary movements. Rarely bilateral

athetosis may develop during adolescence as a progressive disorder terminating in generalized rigidity, as a result of degeneration of the corpus striatum described by the Vogts as *état dysmyélinique*. Athetosis may rarely occur as a symptom of hepato-lenticular degeneration, and very rarely bilateral athetosis may develop in adult life

Unilateral Athetosis.

Unilateral athetosis may also be congenital, being then usually associated with infantile hemiplegia. The brain in such cases may exhibit the Bielschowsky type of cerebral hemi-atrophy, in which there is an elective necrosis of the third cortical layer of the pre-central convolution, atrophy of the thalamus, and a condition of the striatum described by the Vogts as *état fibreux*, or false porencephaly may be present. Unilateral athetosis may also occur as a result of focal lesions involving the corpus striatum at any age, due, for example, to acute encephalitis or a cerebral vascular lesion compli-cating the specific fevers in childhood, but it is more commonly seen in late middle life and old age, as a result of focal cerebral softening secondary to atheroma.

Symptoms.

Congenital athetosis is not usually noticed until the child is several months old, when abnormal postures or movements attract the mother's attention. Athetosis caused by an acute inflammatory or vascular lesion of the brain may develop rapidly within a few days of the lesion, or insidiously after an interval of several weeks, when the shock has passed off.

Typical athetosis possesses the following features One or both halves of the body may be involved The muscles innervated by the cranial nerves are always much more severely affected when the athetosis is bilateral than when it is unilateral In bilateral athetosis the patient exhibits frequent grimaces resembling caricatures of normal facial expressions of all kinds. The tongue is the site of writhing movements, of protrusion and withdrawal, and the patient *is often unable to maintain it protruded unless it is held between the teeth* The involuntary movement of the bulbar muscles leads to dysarthria and dysphagia The head may be rotated to one or other side, or extended. In unilateral athetosis the facial movements usually consist of little more than an exaggeration of normal expres-sions. In the upper limbs the peripheral segments exhibit the in-voluntary movements to a greater extent than the proximal segments. The limb is usually adducted and internally rotated at the shoulder and semiflexed at the elbow. The characteristic posture of the hand

is one of marked flexion of the wrist, with flexion at the metacarpophalangeal and extension at the interphalangeal joints, the posture produced by contraction of the interossei, and the thumb is usually adducted and extended at the two distal joints. This posture is disturbed by slow, writhing movements of flexion and extension at the wrist and at the metacarpo-phalangeal joints, the fingers remaining extended at the interphalangeal joints, with varying degrees of adduction and abduction of the fingers. Movements may also occur at the shoulder and elbow, leading sometimes to retraction and internal rotation at the shoulder and extension at the elbow. In severe cases of unilateral athetosis the patient characteristically grasps the affected upper limb with the normal hand, to restrain the movement. Except in the mildest cases the movements completely interfere with the voluntary use of the limb. The movements of the lower limb are usually less severe than those of the upper, and again are most marked in the distal segments. The foot is usually maintained in the position of talipes equino-varus, often with marked dorsiflexion of the great toe. Athetotic movements are always exaggerated by an attempt to use the limbs in voluntary movement and by nervousness and excitement. They diminish when the patient lies down and disappear during sleep. Though the tone of the muscles is exaggerated during the movements, if sufficient relaxation can be obtained, they are usually found to be hypotonic in the intervals. In severe cases, especially of unilateral athetosis, muscular contractures usually develop and the peripheral segments of the limbs become fixed in their characteristic postures.

Diagnosis.

The involuntary movements are so distinctive that diagnosis is easy. Choreic movements are more rapid and jerky: those of torsion-spasm slower and to a greater extent around the long axis of the limbs and trunk. Athetosis, in fact, is midway between chorea and torsion-spasm. The age and mode of onset distinguish the cause as either congenital abnormality, progressive degeneration, or acute focal lesion.

Prognosis and Treatment.

The medical treatment of athetosis is disappointing. Hyoscine and sedatives such as phenobarbital may slightly diminish the movements, and some improvement may follow re-educational exercises perseveringly carried out over a long period. Extensive section of the posterior roots innervating the upper limb has been advocated. Horsley and others—recently Bucy and Buchanan—have abolished the movements by excising an area of the precentral convolution

corresponding to the affected limb. Putnam's operation of division
of the extra-pyramidal tracts in the anterior column of the spinal
cord above the cervical enlargement may greatly improve the
patient's control over the limbs.

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7. CHOREA

Sydenham's Chorea

Synonym: St Vitus' Dance

Definition: An acute toxi-infective disorder of the nervous system,
usually due to acute rheumatism, occurring in childhood and adoles-
cence and characterized by involuntary movements as its most
prominent symptom.

Pathology.

Cases of chorea which have come to autopsy have often shown
diffuse changes in the brain. Macroscopically oedema and congestion
have been observed. Microscopically the changes have usually been
most marked in the corpus striatum, substantia nigra, and corpus
Luysii, but cortical abnormalities have also been present. Vasodilata-
tion is conspicuous, but perivascular infiltration with lymphocytes
and plasma cells, though sometimes present, is exceptional. There
is a diffuse degeneration of ganglion cells, and sometimes perivascular
patches of degeneration with compound granular cell infiltration
and neuroglial reaction have been described.

Aetiology.

The large majority of cases of chorea in childhood are due to
acute rheumatism, as is shown by the frequency with which other
rheumatic manifestations are present or subsequently develop.
Other infections may, however, be the cause, especially scarlet fever
and diphtheria; and choreiform movements may be encountered as
a symptom of encephalitis lethargica or as a rare complication of
chicken-pox.

Heredity may play some part in aetiology, since some families
appear to be unusually susceptible to acute rheumatism, and there

may be a family history either of chorea or of some other rheumatic
manifestation. Left-handedness is also sometimes a predisposing
cause There is a much larger incidence of left-handedness among
sufferers from chorea than among the general population, and even
when the patient is not left-handed other members of the family
may exhibit the peculiarity.

The white race is more susceptible than the coloured races, and
females suffer more than males in the proportion of about three to one.
Chorea is rare before the age of 5 and after 20 ; four-fifths of all cases
occur between the ages of 5 and 15.

Mental stress may play a part in the aetiology. Overwork at
school may be a predisposing factor, and it is not uncommon for the
onset of the attack to be ascribed to a fright. In a small number of
cases chorea occurs during pregnancy—chorea gravidarum. That
psychical factors may be in part responsible for this is suggested by
the fact that it is relatively commoner in illegitimate pregnancies.
There is often, however, a rheumatic history in such cases, and
other rheumatic manifestations may be present. Chorea gravidarum
usually occurs during the first pregnancy and may recur in subsequent
pregnancies. It rarely occurs for the first time in a multipara or after
the age of 25 Thyrotoxicosis is a rare cause

Symptoms.

Mode of Onset

The onset of chorea is usually insidious, the first complaint being
often that the child is clumsy and drops things. When the movements
are noticed it is described as restless, fidgety, or unable to keep still.
Sometimes the onset is more abrupt and is then often ascribed to a
fright

Involuntary Movements.

Involuntary movements are the most prominent symptom of
chorea Choreic movements are best described as quasi-purposive.
They are movements of a high order, and although they achieve
no purpose they often resemble fragments of purposive movements
following one another in a disorderly fashion. In the face the move-
ments are always bilateral. Frowning, raising the eyebrows, pursing
the lips, smiling, and bizarre movements of the mouth and tongue
occur The protruded tongue may be held between the teeth to
prevent its sudden withdrawal. The eyes may be rolled from one
side to the other, the head turning in the same direction.

In mild cases the speech is not affected ; in severe cases there is
considerable dysarthria, articulation being slurred and words some-
times being jerked out explosively. In severe cases also mastication

and swallowing may be so severely disturbed that the patient requires to be artificially fed.

In the upper limb movements occur at all joints. At one moment the elbow may be flexed and the fingers grasping the bedclothes; at the next the arm may be flung out in full extension. Respiration is often jerky and irregular and is frequently impeded by movements involving the abdominal wall and movements of rotation or flexion of the spine. Movements of the lower limbs are usually less conspicuous and are most evident at the periphery. Choreic movements are intensified by voluntary effort and by excitement They disappear during sleep.

Associated Movements.

In chorea the involuntary muscular contractions normally associated with strong voluntary movement are exaggerated and at the same time inco-ordinate. When the patient clenches his fist, vigorous associated movements may occur in the face, trunk, and limbs Yet observation shows that even the synergic extension of the wrist associated with strong flexion of the fingers is not normally carried out Contraction of the flexors may conflict with, and even overpower, that of the extensors, while the radial and ulnar extensors may not contract synchronously, so that the hand deviates from side to side This disturbance of associated movement is an early sign of chorea which may precede active involuntary movements and can be elicited in suspected cases by asking the patient to clench his fists over the observer's fingers, while protruding the tongue

Voluntary Movement

In mild cases voluntary power is little impaired, though the movements have an abrupt character. For example, if the patient be asked to stretch out the arms, he does so with a sudden movement as though he were flinging his hands away from him. In severe cases *the involuntary movements cause considerable inco-ordination, and* voluntary power may thus be impaired. Muscular weakness may be very marked, as in so-called *paralytic chorea*, though complete paralysis never develops.

Hypotonia and Posture.

Hypotonia is invariably present in chorea and is best demonstrated by passively extending the wrists and ankles, when a considerable degree of hyperextension can be obtained. The so-called choreic posture of the hand, in which the thumb and fingers are hyperextended at the metacarpo-phalangeal joints and the wrist is flexed, *is merely a manifestation of muscular hypotonia*, being an

exaggeration of the normal attitude resulting from loss of tone in the antagonistic muscles. The upper limbs characteristically are hyper-pronated when outstretched and held above the head.

Reflexes

The cutaneous reflexes in chorea are often exceptionally brisk; the plantar reflexes are flexor. When hypotonia is extreme, the tendon reflexes may be difficult to elicit, but they are usually obtainable and sometimes show a characteristic prolongation of the muscular contraction.

Sensory changes do not occur, and there is no disturbance of the sphincters.

Mental State

Most choreic children exhibit some emotional instability, but they are often above the average in intelligence. In severe cases there may be a persistent state of excitement associated with insomnia—so-called maniacal chorea.

The Heart.

Since in most cases chorea is due to acute rheumatism it is not surprising that cardiac abnormalities are common. They are not, however, constant. When the heart is involved for the first time during the attack of chorea, the pulse-rate is quickened, the first is usually slight cardiac dilatation indicated by outward displacement of the apex beat, the apical first sound is somewhat muffled, and there is often a soft systolic murmur in the mitral area. These signs point to myocarditis. When the heart has been affected in previous attacks of rheumatism, signs of valvular damage are more likely to be present. Pericarditis, arthritis, and rheumatic nodules are rarely associated with chorea. Pyrexia is usually absent, unless chorea is complicated by mental excitement or by other manifestations of acute rheumatism.

Diagnosis.

The diagnosis of chorea is usually simple, since the involuntary movements are distinctive. It is most likely to be confused with habit spasm, in which, however, the same movements are repeated again and again. In athetosis the movements are slower than in chorea and have well been described as mobile spasm. Moreover, in most cases, athetosis in childhood is congenital in origin or is noticed before the age of 5, when chorea is very rare. Hysterical involuntary movements may simulate chorea. These usually occur after the age of 15, and in females, and are an imitation of a case of true chorea. The imitation, however, is never exact. The movements

are usually more jerky than those of chorea, and are sometimes rhythmical. There is neither exaggeration nor disorganization of associated movements, and the face usually escapes.

Paralytic chorea may simulate other forms of paralysis in childhood It is distinguished from hemiplegia by the fact that the upper limb alone is paretic, and by the absence of signs of a pyramidal lesion, especially an extensor plantar reflex The absence of wasting and of changes in the electrical reaction of the muscles distinguishes it from poliomyelitis. A further diagnostic point is that even in the weak limb slight involuntary movements are present, and they may also be observed elsewhere in the body

In maniacal chorea the mental state may overshadow the physical symptoms, but the history of precedent involuntary movements or the presence of signs of endocarditis may enable the correct diagnosis to be made.

Chorea having been diagnosed, the cause can usually easily be ascertained. Many cases will show other evidences of the rheumatic infection Even if these are absent, if there is no history of some other infection rheumatism is the most likely cause. Confusion has arisen in the past from cases of encephalitis lethargica characterized by choreiform movements, though these have not been observed for many years In such cases the characteristic lethargy is often absent, and the movements are often associated with insomnia and mental excitement. Ocular symptoms, however, may be present, especially an impairment of the pupillary reflexes, and possibly diplopia, and an excess of mononuclear cells may be found in the cerebro-spinal fluid.

Huntington's chorea is distinguished by its onset in later life, usually after the age of 30, by its strong hereditary character, and by its association with progressive dementia.

Prognosis.

Death from chorea is rare and occurs in only 2 per cent. of cases Most patients recover in from two to three months, rarely in less than six weeks. Recurrences occur in about one-third of all cases: a patient may have two, three, four, or even more attacks. The average intervals between attacks is about one year; it is rarely more than two years. The presence of other rheumatic manifestations, e g. valvular lesions, does not appear to influence recovery from chorea, but the occurrence of repeated attacks of chorea predisposes to the development of rheumatic carditis and endocarditis. Chorea, as such, leaves no serious sequels, though some mental instability may persist for a long time, and slight involuntary movements may be perpetuated as a habit.

Treatment.

All patients suffering from chorea should be kept in bed for at least four weeks, and should then be allowed to get up only if the movements are considerably diminished in severity. The presence of cardiac complications will probably necessitate a longer stay in bed, and the condition of the heart must be considered independently. Isolation of the patient is beneficial, and if possible the child should be nursed in a room by itself. In the hospital ward isolation may be obtained by the use of screens round the bed. Excitement is to be avoided, but in all but the most severe cases some quiet occupation should be provided. When the movements are very severe it may be difficult to keep the patient in bed and more convenient to nurse him upon a mattress placed upon the floor. Special attention must be devoted to the care of the skin, and bony points which are liable to be abraded by being rubbed against the bedclothes in movements should be protected by lightly bandaging them with cotton-wool. The diet should be ample. If dysphagia is very severe it may be necessary to feed the patient by means of a tube. Aspirin is the most generally useful drug, both because it acts as a sedative and because it may have a specific action upon the rheumatic organism. It may be given in doses of from 5 to 15 gr. of calcium aspirin thrice daily, or more often if necessary. In mild cases no other sedative will be required, but in the more severe cases, especially when there is mental excitement, it may be necessary to give bromide, chloral, or phenobarbital. The last of these three is perhaps the most effective, and may be given in doses of from ½ to 1 gr. two or three times a day. If necessary, it can be injected subcutaneously, 1–3 gr. of phenobarbital sodium being given in 20 per cent. solution.

Nirvanol, phenylethylhydantoin, is a drug which is remarkably effective in the treatment of some cases of chorea. It is given by the mouth twice daily in doses of 0.15 gm. until a reaction appears. This usually develops after about ten days and is characterized by fever, quickened pulse-rate, and a rash. The temperature may rise to 102° F. and the pulse rate to 120 or higher. It is clear that to obtain good results marked symptoms of intoxication with nirvanol must be produced, and since in most cases recovery from chorea occurs in response to less drastic methods of treatment, it is wise to restrict the use of nirvanol to very severe cases. The same applies to treatment by means of artificial pyrexia.

During convalescence attention should be paid to re-education of the movements of the limbs. This is best promoted at first by occupations requiring fine manipulation, such as knitting, sewing, bead threading, drawing, and painting. These, however, are of

little value unless carried out under supervision. When the child is up, and if the cardiac condition permits, Swedish remedial exercises may be added.

The influence of infected tonsils upon chorea and other rheumatic manifestations is difficult to assess. The tonsils should only be removed when there is a history of repeated sore throats and their condition clearly warrants the operation. This should not be performed until the child is convalescent from chorea, but the fact that some movements persist is not a contra-indication.

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HUNTINGTON'S CHOREA

Definition. A hereditary disorder characterized pathologically by degeneration of the ganglion cells of the forebrain and corpus striatum, and clinically by choreiform movements and progressive dementia, which usually begin during early middle life.

Pathology.

The brain is small and of diminished weight, the reduction being chiefly, if not entirely, in the forebrain, which shows evidence of marked atrophy affecting the convolutions and especially the corpus striatum. The ganglion cells in both the caudate nucleus and in the putamen are reduced in numbers and sometimes almost absent. According to Dunlap, the putamen is more affected than the caudate nucleus and suffers most severely in its second and third fourths. This observer found no loss of cells and no evidence of primary disease in the globus pallidus. Such shrinkage in size as occurred in the latter appears to be due to destruction of fibres coming from the caudate nucleus and putamen. The degenerative changes are accompanied by an extensive proliferation of neuroglia. The ganglion cells of the cortex are small and shrunken in appearance, and the white matter of the cerebral hemispheres is reduced in amount, possibly more than the grey.

Aetiology.

Huntington's chorea is very rare in Great Britain but is not uncommon in the United States of America. Though sporadic cases are occasionally encountered, the only known cause is heredity, and the disorder is inherited as a Mendelian dominant. According to Davenport and Muncey its ancestral source in the United States can be traced to three brothers who migrated there in the seventeenth century. Of a thousand cases in certain districts practically all could be traced to six individuals, and transmit the disease with equal frequency. Both sexes are affected and transmit the disease with equal frequency. The age of onset of symptoms is usually between 30 and 45, but may be either later or earlier. Exceptionally members of affected sibships have developed the disease in childhood.

Symptoms.

The first symptom is usually involuntary movements, which develop insidiously. They are most conspicuous in the face and upper limbs, and are usually more rapid and jerky than the movements of Sydenham's chorea. As the disorder progresses they lead to dysarthria and ataxia of the upper limbs and of the gait. Mental changes gradually develop, usually a few years after the onset of the involuntary movements. They consist of a progressive dementia. Most patients become inert, apathetic, and irritable. Delusions may occur, and outbursts of excitement are not uncommon. Suicide is exceptional.

As Davenport and Muncey have shown, the clinical picture does not always exhibit the classical features just described. Dementia may precede involuntary movements or the latter may never appear. An example of this has recently been reported by Curran. Alternatively involuntary movements may not be followed by dementia. The onset of symptoms in childhood has already been mentioned, and it is stated that in some such cases the disorder after a time ceases to progress.

Diagnosis.

In typical cases with a family history the diagnosis is easy. In sporadic cases progressive dementia developing in middle life in association with involuntary movements which somewhat resemble tremor may lead to a diagnosis of general paralysis. This, however, can easily be excluded by the absence of irridoplegia and by the negative serological reaction. Cerebral arteriosclerosis, which may lead to both dementia and choreiform involuntary movements, does not usually develop until late middle life or old age.

Prognosis.

Save in rare cases, the disorder is progressive and terminates fatally, usually in from ten to fifteen years, though it may be much more acute, and on the other hand survival for twenty or thirty years is not uncommon.

On account of the dominant heredity, half the children of an affected person may be expected to develop and to be capable of transmitting the disease Those who remain free from it will not transmit it, but, unfortunately, since symptoms usually do not develop until middle life, *it is impossible in the case of children of an affected parent to decide whether they will transmit the disorder until they have passed the usual age of marriage.* When, however, *the parent has reached the age of 60 without developing symptoms,* it may be assumed that his children are unlikely to develop, and hence to transmit, the disease

Treatment.

The onset of the mental deterioration frequently necessitates institutional care. No form of treatment is known to arrest the progress of the dementia or to control the involuntary movements

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SENILE CHOREA

Choreiform movements may follow vascular lesions of the brain in middle life and old age. Their onset is usually sudden, and they are generally unilateral. Haemorrhage into the corpus Luysi causes violent hemichorea on the opposite side (Martin). Chronic

progressive chorea occasionally occurs in the absence of hereditary
predisposition. The large and small cells of the caudate nucleus
and putamen degenerate but the cerebral cortex is spared (Alcock).
It is difficult to distinguish this from the sporadic occurrence of
Huntington's chorea, though it has been stated that the age of
onset of senile chorea is usually later than that of Huntington's
variety and that mental symptoms are less likely to occur. Other-
wise the symptoms and prognosis are those of Huntington's chorea.

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CONGENITAL AND DEGENERATIVE DISORDERS

1. CONGENITAL DIPLEGIA

Synonyms: Congenital spastic paralysis, Little's disease, atrophic lobar sclerosis.

Definition: The term 'congenital diplegia' is now used to include a group of cases characterized by bilateral and symmetrical disturbances of motility, which are present from birth and which subsequently remain stationary or show a tendency towards improvement. Though commonly the lesion involves chiefly the pyramidal tracts, causing weakness and spasticity which are most conspicuous in the lower limbs, mental defect, involuntary movements, and ataxia may be present either in association with spastic weakness or as the sole manifestations of the cerebral lesion.

Aetiology and Pathology.

There has been much discussion concerning the aetiology of congenital diplegia, and five principal theories have been put forward. The view that most cases were due to injury to the brain at birth through meningeal haemorrhage was one of the earliest to gain acceptance. It was later thought that asphyxia at birth might cause the condition in the absence of meningeal haemorrhage. Since a proportion of diplegic infants are premature, the condition has been ascribed to an arrest of myelination of the nervous system following premature birth. During the present century the view has been gaining ground that the damage responsible for the diplegia occurs comparatively early in foetal life and that an arrest in development or an actual degeneration of certain parts of the nervous system occurs *in utero*. Finally, congenital diplegia has been ascribed to gross maldevelopment of the brain.

Although the attribution of congenital diplegia to meningeal haemorrhage at birth appears plausible at first sight, there are serious objections to it. The pathology of cerebral birth-injury has now been thoroughly investigated, and it is recognized that meningeal haemorrhage is usually unilateral, and when bilateral is rarely symmetrical. Though it may sometimes be responsible for congenital hemiplegia, it is unlikely to cause a symmetrical disturbance of function similar to that found in diplegia. Moreover, in many cases of diplegia labour is easy.

It seems unlikely also that asphyxia at birth can cause diplegia,

since many infants survive it without injury and again many diplegics are not exposed to it.

It is equally difficult to accept prematurity as a cause, since most premature infants develop perfectly normally, and many diplegic infants are born at full term.

Pathological investigations support the view first put forward by Freud and Collier that in most cases of diplegia the arrest of development or the onset of degeneration occurs *in utero*. The commonest pathological finding is a condition which has received the name 'atrophic lobar sclerosis'. This is characterized by a symmetrical atrophy of both cerebral hemispheres with the destruction of *nerve-cells* and *glial proliferation*. *To the naked eye atrophy is* apparent, and may be either diffuse or more or less localized. The convolutional pattern of the hemispheres is usually normal but is *sometimes primitive*. The atrophied convolutions are firmer than normal According to Buzzard and Greenfield the condition is one of neuroglial overgrowth associated with degeneration of the neurones, a process affecting primarily the deeper layers of the cortex and spreading to the underlying white matter and to the superficial layers of the cortex. It is probable that the neuroglial hyperplasia is secondary to the neuronic degeneration. The cause of the latter is unknown, but it has been suggested by Patten that an interference with myelination may come about in foetal life, owing to some maternal abnormality.

A somewhat similar pathological condition localized to, or predominant in, the corpus striatum is responsible for congenital double athetosis. This is the *état marbré* of the corpus striatum described by Oppenheim and C. Vogt, and so called because to the naked eye a section of the corpus striatum presents a marbled appearance. Microscopically there is atrophy of the ganglion cells, which are *replaced by a dense mesh of fine fibres filling the spaces between* islands of more healthy tissue. The caudate nucleus and putamen are more severely affected than the globus pallidus.

Gross maldevelopment of the brain is probably a rare cause of congenital diplegia, but in some cases the convolutions have exhibited a primitive foetal pattern and the cortical ganglion cells have been primitive and confined to one layer. The corpus callosum may be absent. Bilateral true porencephaly is due to abnormal cerebral development, which leaves a *free communication between the lateral* ventricle and the surface of the hemisphere, but this condition, involving as it does the lower part of the hemispheres, is more likely to cause double hemiplegia with marked spasticity and weakness of the upper limbs than diplegia, in which the upper limbs are less severely affected than the lower.

Microcephaly, which is present in 35 per cent of cases (Ford), is the result of the cerebral hypoplasia and not its cause, the size and shape of the skull depending upon those of the brain

Exceptionally congenital diplegia appears in several siblings, and this is sometimes the case with double athetosis. Congenital syphilis is a rare cause of diplegia

Symptoms.

The symptoms depend upon the distribution of the degenerative changes in the brain. These may predominate in the prefrontal region which is concerned especially with psychical functions, in the pre-central convolutions, or in the subordinate centres concerned in motility and its co-ordination. Thus one function may be affected almost alone, with the production of types of congenital diplegia characterized by the predominance of (1) mental deficiency, (2) spastic weakness, (3) involuntary movements, and (4) cerebellar deficiency. Mixed varieties, however, are common

Frequently nothing abnormal is noticed about the child at birth and for some time afterwards, though diplegic infants are often difficult to feed. In some cases microcephaly and muscular rigidity are so marked that attention is drawn to them early. Usually the child is only regarded as abnormal when it fails to reach one of the landmarks of normal development at the expected time Thus it may be observed that it fails to take notice of its surroundings, that it does not begin to raise its head when 3 months old, sit up at 6 months, and begin to walk and talk at the end of the first year of life. Diplegic children, too, are usually late in acquiring control of the sphincters.

Mental Defect.

Mental defect may be the predominant symptom and then may occur in the absence of any gross disturbance of motility, except such clumsiness as results from an inability to learn to control the limbs. In other cases mental defect is associated with diplegia. It ranges through all the degrees arbitrarily characterized as idiocy, imbecility, and feeble-mindedness, up to slight backwardness. Frequently the diplegic child appears to be more defective mentally than is actually the case, since its slowness in learning to walk and its clumsiness in using its hands retard its mental development. Such children, though developing late, may ultimately achieve a high degree of intelligence in spite of severe motor disabilities.

Weakness and Spasticity.

These symptoms, which are mainly attributable to defective development of the pyramidal tracts, are usually remarkably

symmetrical on the two sides. Rarely one side is more affected than the other. The lower limbs are always more severely affected than the upper. The severity of the symptoms of pyramidal defect varies greatly in different cases. When at its slightest, power and tone may be almost normal, the sole indications of the lesion being exaggerated knee- and ankle-jerks, extensor plantar responses, and slight contractures of the calf muscles, leading to a moderate degree of talipes equino-varus. A somewhat more severe lesion causes a spastic paraplegia of the type originally described by Little, in which weakness and spasticity are confined to the lower limbs and the muscles of the lower trunk. The lower limbs are rigid in a position of plantar flexion of the ankle, extension at the knee, and adduction and internal rotation at the hip, and contractures develop in the spastic muscles Voluntary power is often fairly strong, though much hampered by the spasticity. The gait is characteristic, since the plantar flexion of the feet causes the child to walk on the toes, while owing to adduction of the hips the knees may rub together, or may be actually crossed, the so-called 'scissors gait'. The tendon reflexes in the lower limbs are much exaggerated, and the plantar reflexes are extensor The abdominal reflexes are frequently brisk in spite of the severity of the pyramidal lesion. Spinal deformities, such as lordosis and scoliosis, are common

In the most severe cases the upper limbs and bulbar muscles suffer from spastic weakness as well as the lower limbs. In the upper limbs *the rigidity is usually most marked in the flexor muscles, and the* involvement of the bulbar muscles leads to spastic dysarthria and in severe cases to dysphagia. Dribbling of saliva is common.

Involuntary Movements.

Involuntary movements may be athetotic or choreiform, or may present some of the features of both, being then described as choreoathetoid. The characteristics of these involuntary movements are described elsewhere; see pp. 533 and 536 In the double athetosis of Oppenheim and Vogt athetotic or choreiform movements are *present on both sides of the body and are increased by voluntary* and emotional movements The involuntary movements are most evident in the slighter cases, being replaced by hypertonia in the most severe examples of the disorder. The face is expressionless in repose, but involuntary laughing and crying frequently occur. There are gross disturbances of articulation, phonation, mastication, and deglutition, and voluntary movement of the limbs is slow and clumsy. In typical double athetosis there is no clinical evidence of damage to the pyramidal tracts and the plantar reflexes are flexor, but it is not uncommon to find athetotic or choreiform movements

associated with spastic diplegia of the type described in the previous section

Cerebellar Diplegia

In this rare form of diplegia there is marked hypoplasia of the cerebellum, and the symptoms are those of cerebellar deficiency, especially nystagmus, hypotonia, and ataxia.

Other Symptoms.

Primary optic atrophy may be associated, though rarely, with any of the forms of diplegia already described The child may be blind from birth, and I have known more than one case in which it was brought under observation on this account Squint and nystagmus are common in diplegic children, and epilepsy occurs in a small proportion of cases. A moderate degree of skeletal infantilism is usually present, and puberty is not uncommonly delayed

Diagnosis.

In most cases diagnosis is easy, since the symptoms have clearly been present since birth The presence of muscular rigidity readily distinguishes diplegia from amyotonia congenita and progressive spinal muscular atrophy of infants, in both of which conditions the muscles are flaccid. It is important to distinguish congenital diplegia from progressive degenerative disorders of the brain developing in early life, such as cerebro-macular degeneration and diffuse sclerosis, both of which lead to bilateral spastic weakness The distinction is based upon the fact that in these two disorders the child is normal at birth and develops normally during the early months of its life, and symptoms, when they develop, become progressively worse, whereas in congenital diplegia the child is abnormal from the beginning and its condition remains stationary or slowly improves

Prognosis.

The prognosis of congenital diplegia depends upon its severity and especially upon the degree of mental defect present In the most severe cases the child rarely survives more than a year or two, usually succumbing to pneumonia. Even when the disability is only moderately severe, few affected individuals survive beyond the early years of adult life. Although some patients remain stationary, there is usually a very slow improvement in the motor symptoms, both in the group characterized by spastic weakness and in that in which involuntary movements predominate, but this depends chiefly upon the mental state of the patient, and little improvement can be expected when a severe mental defect is present. In favourable cases

it may be expected that a child will learn to walk, even though it may not do so until it is 5 or 6 years old.

Treatment.

Treatment consists essentially of the education of movement combined with the removal as far as possible of the obstacles which result from contractures and deformities. Much, therefore, depends upon the patience and care which are available for the education of the patient. Every effort must be made to help the child to learn to walk, and by means of simple games and occupations involving manipulative skill it must gradually be taught control over the movements of the upper limbs. Massage, combined with passive movements, is of value. Contractures must be dealt with by tenotomy, and in addition severe adductor spasm may be relieved by dividing the obturator nerve. Stoffel's operation, a partial section of the nerves supplying the spastic muscles, has achieved good results in the hands of experienced operators. These operations, however, should only be carried out in children whose mental capacity and voluntary power will enable them to profit by them. Epilepsy must be treated in the usual way.

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2. CONGENITAL AND INFANTILE HEMIPLEGIA

Definition: 'Congenital hemiplegia' is self-explanatory, 'infantile hemiplegia' is the term applied to hemiplegia which develops during the first few years of life. Like hemiplegia in adult life, it is a symptom of a large variety of pathological states.

Aetiology.

The causation of hemiplegia in childhood is in many cases obscure, and pathological investigations of acute examples comparatively few. The most convenient classification is, therefore, one based upon the clinical features and associations of the hemiplegia, and we may recognize the following varieties: (1) congenital hemiplegia, (2) hemiplegia complicating known infections, (3) hemiplegia of acute onset in the absence of any evident predisposing cause, (4) hemiplegia of slow onset.

(1) Congenital hemiplegia is rare. There is a history of difficult labour in a large proportion of such cases, and the commonest cause is probably intracranial haemorrhage occurring during birth. Less often the condition may be due to a congenital cerebral deformity, such as true porencephaly, aplasia of the cerebral hemisphere, intracranial angioma, or a cerebral vascular lesion or encephalitis occurring during foetal life.

(2) Hemiplegia may occur as a complication of many acute infective disorders of childhood, but is much commoner in some than in others. Whooping cough is one of the commonest causes. Less frequently it occurs in association with measles, scarlet fever, diphtheria, chicken-pox, small-pox, vaccinia, pneumonia, otitis media, septicaemia due to pyogenic organisms, typhoid fever, typhus, dysentery, mumps, chorea, encephalitis lethargica. The relationship of the hemiplegia to the infection which it complicates is often obscure. In many cases the cerebral lesion is a vascular one. Thus meningeal and intracerebral haemorrhage have frequently been described in whooping cough, and arterial thrombosis and embolism have been observed in diphtheria. Cerebral thrombosis, too, appears to be the commonest cause of hemiplegia in typhoid and typhus fevers and either cerebral venous thrombosis or cerebral abscess or meningitis may cause hemiplegia in cases of otitis media. In scarlet fever so-called 'acute haemorrhagic encephalitis' has been reported, while in small-pox, chicken-pox, vaccinia, and measles the lesion in most cases is a demyelinating encephalitis, which is regarded by some as due to the infecting organism and by others as caused by a secondary infection. Acute poliomyelitis has been held responsible for the majority of cases of infantile hemiplegia of acute onset, but there is little evidence in favour of regarding it as a common cause of this condition. Actually hemiplegia is a rare occurrence in epidemics of anterior poliomyelitis. Congenital syphilis and tuberculous meningitis are rare causes.

(3) Cases of hemiplegia occurring in early childhood without any obvious predisposing cause are slightly more frequent than those

which fall within the preceding group. This syndrome has been described as the Marie-Strümpell or Strümpell-Leichtenstern type of encephalitis, and Strümpell at first considered that the hemiplegia was the result of infection of the brain with the virus of acute poliomyelitis. As already stated, there is little evidence that this organism is anything but a very exceptional cause of the syndrome. In some cases the hemiplegia is probably a manifestation of an encephalitis or toxic encephalopathy of unknown origin. In others it may be due to a vascular lesion, the cause being haemorrhage or thrombosis, especially haemorrhage from an angioma or aneurysm, or subdural haematoma.

Infantile hemiplegia usually develops during the first three years of life and rarely after the age of 6.

(4) Hemiplegia of slow onset is very rare in childhood. The causes include intracranial tumour, arising either in one cerebral hemisphere or in the pons, cerebral tuberculoma, and diffuse sclerosis.

Pathology.

The pathological changes, as might be expected, are very varied. Cases which are examined shortly after the onset of the hemiplegia frequently show focal vascular lesions, including meningeal and intracerebral haemorrhage and arterial thrombosis. Wiesel has described destructive changes in the cerebral arteries leading to necrosis of the media and atheroma in children who died of acute infective diseases. In some cases the pathological picture has been so-called 'acute haemorrhagic encephalitis', and a form of encephalitis characterized by perivascular demyelination occurs in small-pox, chicken-pox, vaccinia, and measles. In brains examined long after the onset of the hemiplegia the changes commonly found are meningeal thickening, localized atrophic sclerosis, cysts, and pseudo-porencephaly.

Symptoms.

Congenital hemiplegia is usually detected at an early age, because it is observed that the child does not move the affected arm and leg normally, or because these limbs feel rigid.

Infantile hemiplegia usually develops suddenly. When it occurs as a complication of an existing infective disease hemiplegia does not usually develop until some days after the onset of the infection, usually during the second week and sometimes not until the patient is convalescent. Convulsions occur at the onset in a large proportion of cases. Consciousness is lost and the convulsive movements frequently predominate upon and may be confined to the side which

subsequently becomes paralysed. Usually a series of fits occurs during twenty-four hours and the patient remains comatose for a variable period, *sometimes for several days after the convulsions stop.* Headache, vomiting, delirium, and pyrexia frequently usher in the fits. During the stage of coma the limbs on the affected side are found to be completely flaccid and the plantar reflex is extensor. When the patient recovers consciousness he is hemiplegic, and when the right side of the body is paralysed, not uncommonly aphasic also, and sometimes mentally defective. In less severe cases hemiplegia may develop without convulsions and without loss of consciousness. The cerebro-spinal fluid may be normal or may show an increase in the protein content, red blood cells, or a leucocytosis, depending upon the nature of the cerebral lesion. A facial naevus may be present in a patient with a cerebral angioma.

In favourable cases improvement occurs, and in a few weeks or months recovery may be complete. When the hemiplegia does not recover, flaccidity gives place to spasticity in the course of a few weeks and the condition of the limbs on the paralysed side comes to resemble that found in congenital hemiplegia. The upper limb is severely affected as well as the lower and usually becomes spastic in an attitude of flexion, less often in extension. The signs of hemiplegia are described elsewhere, see p. 6. Owing to the early age of onset the development of the paralysed limbs is retarded and they remain smaller than those of the normal side. Contractures readily develop in both upper and lower limbs. When the paralysis is *incomplete involuntary movements of an athetoid or choreic character* frequently develop on the affected side. Epilepsy is much commoner in infantile hemiplegia than in cerebral diplegia and develops in over 50 per cent of cases. The convulsions usually begin with tonic spasm or clonic movements of the paralysed side, but rapidly become generalized and are attended by loss of consciousness.

Diagnosis.

Congenital hemiplegia is readily recognized, hemiplegia acquired in childhood must be distinguished from paralytic chorea, which is preceded by involuntary movements, and acute poliomyelitis which is rarely limited to one upper and lower limb and which is characterized by loss of tendon reflexes and muscular wasting. When the child is seen during the acute stage of a cerebral disturbance the subsequent development of hemiplegia cannot always be anticipated, but the occurrence of repeated convulsions, especially if these are predominantly unilateral, should suggest this possibility.

Hemiplegia of gradual onset is rare in childhood and is usually due

to intracranial tumour or tuberculoma. Encephalography or ventriculography may be helpful in difficult cases.

Prognosis.

Little improvement is likely to occur in congenital hemiplegia, but in mild cases careful education may enable the child to make some use of the paralysed limbs. It is exceptional for the lesion responsible for acquired infantile hemiplegia to prove fatal, but if the child shows no signs of returning consciousness forty-eight hours after the onset of the convulsions the outlook for recovery is bad. The more severe the symptoms of the acute stage, the more likely are mental defect, aphasia, and hemiplegia to be persistent. Nevertheless, there are exceptions to this rule, and for several weeks after the acute stage there is no sure method of deciding to what extent recovery of function will occur. Some patients recover completely, but a considerable proportion remain mentally defective and hemiplegic and of these more than half become epileptic. The hope of considerable improvement should not be abandoned until at least a year has elapsed after the onset of the illness. Even after this lapse of time some increase of power and co-ordination may occur in the paralysed limbs in response to treatment.

Treatment.

In the acute stage of the illness which leads to infantile hemiplegia lumbar puncture is the most valuable method of treatment and should be performed two or three times a day as long as the patient is comatose, sufficient cerebro-spinal fluid being withdrawn on each occasion to restore to normal the pressure, which is usually raised. The convulsions may be controlled by doses of $\frac{1}{4}$ to 1 grain of phenobarbital sodium in 20 per cent. solution subcutaneously and 1 or 2 oz. of a 25 per cent. solution of magnesium sulphate given per rectum may do good by reducing cerebral oedema. Glucose and normal saline should be given rectally as long as the patient is unconscious. The after-treatment of hemiplegia, both of the congenital and of the acquired forms, includes massage and passive movements to diminish the risk of contractures, and the correction of the latter by tenotomy when they develop. When any voluntary power remains, re-educational exercises should be instituted   Stoffel's operation, a partial section of the nerves supplying the spastic muscles, has achieved good results in the hands of experienced operators. Small doses of potassium bromide should be given daily over a period of several years in the hope of preventing the development of epilepsy. Aphasia, when present, must be treated by attempting to re-educate the child's powers of speech.

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3. NERVOUS MANIFESTATIONS OF ICTERUS GRAVIS NEONATORUM: 'KERNIKTERUS'

The involvement of the brain in icterus gravis neonatorum is of interest in view of the association between lesions of the corpus striatum and damage to the liver occurring in hepato-lenticular degeneration and manganese poisoning   Icterus gravis neonatorum is a familial disorder, the cause of which is unknown, but which has been attributed to disease of the foetal liver or blood-forming organs, maternal toxaemia, and an unknown infection

The *pathological changes* consist of general bile-staining of the tissues. There is active blood formation in the liver, spleen, which is enlarged, kidneys, and hyperplastic bone marrow. The liver may be otherwise normal, or may show a centro-lobar necrosis. In the brain *the bile pigmentation is heaviest in the lenticular and caudate nuclei*, less marked in other nuclear masses and in the cortex. The ganglion cells in these regions degenerate. It is uncertain whether the bile staining is secondary to the ganglion cell degeneration, or vice versa.

The infant is usually normal at birth, but becomes jaundiced when two or three days old. Jaundice rapidly deepens. Bile is present, however, in the stools as well as the urine. The bleeding time is prolonged, and spontaneous haemorrhages occur. The child becomes anaemic and primitive red cells are found in the blood. Convulsions, rigidity, and coma mark the damage to the brain.

The mortality rate is high, but about 25 per cent. survive, usually with mental defect and extrapyramidal symptoms, such as chronic chorea or athetosis. When the blood-forming organs alone are affected complete recovery may occur, but how far this is the case *after the brain has been damaged is unknown*. The *treatment is* transfusion with whole blood and otherwise is symptomatic.

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4 CEREBRO-MACULAR DEGENERATION

Synonyms: Tay-Sachs' disease; amaurotic family idiocy.

Definition: A disease of early life, frequently occurring in several
members of the same family, characterized pathologically by wide-
spread lipoid degeneration of the ganglion cells of the brain and
retina, and clinically by progressive mental failure, blindness, and
paralysis.

Pathology.

Several forms of cerebro-macular degeneration have been de-
scribed, differing mainly in the age of onset. The infantile form,
described as amaurotic family idiocy by Waren Tay (1881) and
Bernard Sachs (1887), develops during the first year of life. A late
infantile form of Bielschowsky (1914) begins during the second or
third year, and a juvenile form of Spielmeyer-Vogt (1906) and a
late juvenile form (Kufs, 1925) develop between the ages of 3 and 10,
and 15 and 25 respectively.

Although there are corresponding differences in the pathological
picture, it would seem that the underlying pathological process is
the same. Macroscopically the brain usually shows moderate general
atrophy. Microscopically the characteristic pathological change is
found in the ganglion cells. According to Schaffer the first alteration
is a swelling of the hyaloplasm, which subsequently undergoes a
granular degeneration with the formation of lipoids and lipochrome.
The nucleus is often eccentric, and the dendrites are frequently
swollen. The ganglion cells of the cortex and of the thalamus suffer
severely. The cerebellum is usually more affected in the late infantile
and juvenile forms than in the infantile form. The ganglion cells
of the spinal cord may show similar changes. The white matter
shows tract degeneration. An overgrowth of neuroglia occurs second-
arily to the ganglion cell degeneration. The retina shows changes
similar to those found elsewhere in the nervous system. The gang-
lion cells show granular degeneration. In the forms of later onset
there is degeneration of the external layers of the retina with pro-
liferation of the neuroglia and of the pigment epithelial cells. These
changes are most evident in the region of the macula.

Aetiology.

The disease is frequently familial and occurs in several siblings Though it probably depends upon an inherited predisposition, there is no history of the disorder in previous generations It is probably *inherited as a Mendelian recessive*

The infantile form is confined to the Jewish race, but this is not true of the late infantile and juvenile forms.

The cause of the peculiar degeneration of the ganglion cells is unknown, though both Hurst and Grinker have drawn attention to the resemblance of the pathological changes to those occurring in senile brains. Attempts have been made to relate amaurotic family *idiocy to Niemann-Pick's disease, which is characterized by* widespread intracellular deposition of lipoids throughout the body, and, like the infantile form of amaurotic family idiocy, has a familial incidence in Jewish children during the first year of life. Schaffer, however, points out that amaurotic family idiocy is essentially a degeneration of an ectodermal tissue, whereas in Niemann-Pick's disease mesodermal tissues take part in the reaction and the brain *probably suffers secondarily to a general disturbance of lipoid metabolism* Similar changes in the nervous system have been described in gargoylism. (See p. 841)

Symptoms.

The age of onset of the various forms has already been stated. The symptoms are essentially the same in all forms, consisting of progressive mental deterioration, visual failure, and paralysis

In the infantile form the child is normal at birth and symptoms usually appear between the third and sixth months   The child becomes listless and apathetic and ceases to take notice of its surroundings. It fails to raise its head and to sit up. Convulsions may occur. The retina and optic disk are atrophied, and there is a cherry-red spot visible at the macula, which at this age is pathognomonic. *This is due to severe atrophy of the macular region of the retina,* which renders the vascular choroid visible. Progressive flaccid paralysis of all four limbs develops, and finally the child is completely blind and paralysed and fails to respond to external stimuli, except occasionally by a simple reflex muscular contraction. The retinal atrophy leads to impairment of the reaction of the pupils to light, and squint and nystagmus may be present

In the late infantile and juvenile forms the red spot at the macula is absent and may be replaced by fine pigmentation (Batten-Mayou type of degeneration). Convulsions appear to be commoner in cases of later onset, and flaccidity is replaced by spasticity and contrac-

tures. Sjögren (1931) stresses the gradual development of Parkin-
sonian symptoms in these cases.

Diagnosis.

No other condition exactly simulates the infantile form of the
disease and *the red spot at the macula settles the diagnosis.* Similar
nervous symptoms have been described in Niemann-Pick's disease,
but in this condition the liver and spleen are enlarged. The *juvenile
form may simulate encephalitis periaxialis diffusa,* which is also
characterized by progressive blindness, paralysis, and mental
deterioration. In this condition, however, the blindness is usually
due to degeneration of the optic radiations, and optic atrophy is rare.

Prognosis.

The disease is inevitably progressive, and the younger the patient
at the onset the more rapid the downward course. In the infantile
form death occurs in from one to two years, the terminal stages
being characterized by wasting and anaemia. In the juvenile form
the patient may live for ten or fifteen years.

Treatment.

No treatment is known to influence the disease.

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5. EPILOIA

Synonyms: Tuberous sclerosis; Bourneville's disease; Brushfield and Wyatt's disease.

Definition: A rare congenital disorder characterized pathologically by sclerotic masses in the cerebral cortex, adenoma sebaceum, and tumours in various organs, and clinically by mental deficiency and epilepsy. The term epiloia was coined by Sherlock (1911).

Pathology.

Macroscopically the brain may exhibit microgyria and macrogyria, and absence of the corpus callosum has been described. The characteristic sclerotic patches to which the disease owes its name were first described by Bourneville and Brissaud in 1880. They are found in the cortex of the cerebral hemispheres and are rare in the cerebellum. They are hard to the touch and white in appearance, ranging in size from $\frac{1}{2}$ to 2 cm. in diameter. Microscopically they are composed of glial fibres and contain in addition large cells, some of which are believed to be abnormal ganglion cells, while others are thought to be derived from spongioblasts. Tumour-like masses are also found in the cerebral ventricles and *these appear to be derived* from the ependyma. Occasionally a large tumour, glioblastoma, spongioblastoma, or astrocytoma, has been observed. Circular laminated bodies resembling corpora amylacea have been found scattered throughout the cerebral cortex, cerebellum, choroid plexus, and the tumours themselves, and cystic degeneration is found in the cerebral hemispheres and cerebellum, leading to small cavities which may be traversed by fine fibrils. The ganglion cells of the cerebral cortex are reduced in number and are often atypical. The retinal tumours, phakomas, are composed of neuroglia. Adenoma sebaceum described by Balzar in 1885 and Pringle in 1890 consists of a *hyperplasia of sebaceous glands embedded in a vascular matrix*. Tumours in other situations include rhabdomyoma of the heart, teratoma, and adenosarcoma of the kidney, and tumours have also been described in the thyroid, thymus, breast, and duodenum. Other associated abnormalities which are sometimes present include hydromyelia and spina bifida and congenital malformations of the heart.

Aetiology.

Beyond the fact that tuberous sclerosis is due to a congenital *dysplasia probably occurring at an early stage in embryonic life*, little is known about its aetiology. It is occasionally familial, two or more siblings being affected. The first-born appear more liable to

develop it than later children. Males are affected more often than females. The disorder is confined to the white races and is found especially among the poorer classes. Penrose suggests that it is pro-

FIG. 56. Epiloia: pronounced adenoma sebaceum.
(Kindly lent by Dr. R. M. Stewart)

bably due to a single dominant gene which is subject to modification by autosomal genetic factors. It appears to be closely related to the syndrome of neurofibroblastomatosis.

Symptoms.

Typical sufferers from tuberous sclerosis are mentally defective, being imbeciles of a low grade, and are epileptic. The convulsions usually begin during the first year of life. Both petit mal and major

attacks occur and Jacksonian convulsions have been described. Status epilepticus may supervene In spite of the diffuse distribution of the cerebral lesions spastic paralysis and contractures are rare. A single large tumour will cause general and focal symptoms of an intracranial neoplasm The mental deterioration is progressive and consists of intellectual defect associated with a primitive type of psychosis.

Adenoma sebaceum, which is not invariably present, manifests itself at about the fourth or fifth year of life as a pale pink, slightly raised rash, consisting of discrete spots which fade on pressure and appear first in the nasolabial folds, spreading over the face in a 'butterfly' pattern, sparing the upper lip (Fig 56) A few scattered nodules may also appear on the forehead and neck, but rarely below the clavicles. After the second dentition the adenomas tend to coalesce and darken in colour to a deep red or brown hue Exceptionally the cutaneous lesion does not make its appearance until puberty or early adult life Tumours in other situations occasionally grow large enough to cause symptoms The retinal phakomas, described by van der Hoeve in 1923, are flat, white, round or oval areas about half the size of the optic disk Abortive forms of the disease occur Adenoma sebaceum or epilepsy, or both, may occur without mental defect.

Diagnosis.

Tuberous sclerosis can be distinguished from other causes of mental deficiency associated with epilepsy only by the presence of adenoma sebaceum or of tumours elsewhere

Prognosis.

Most patients die between the ages of 5 and 15 years, though exceptionally an individual may survive to between 30 and 40. Death, if not due to intercurrent disease, usually occurs from status epilepticus and has sometimes been due to a renal tumour.

Treatment.

The mental deficiency usually necessitates institutional treatment, and the treatment appropriate for epilepsy should be carried out.

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6. NEUROFIBROMATOSIS

Synonyms: Neurofibroblastomatosis,   von   Recklinghausen's disease.

Definition: A disease of congenital origin, characterized by cutaneous pigmentation and the formation of tumours in various tissues The commonest of these are cutaneous fibromas, mollusca fibrosa, and perineurial fibroblastomas (neurofibromas), but meningeal fibroblastomas (meningiomas) and gliomas may also occur. Combinations of these abnormalities have been designated as separate syndromes Thus Worster-Drought, Carnegie Dickson, and McMenemy (1937) recognize the following:

1 Central type (1) meningeal and perineurial—syndrome of Wishart (1822) which is rare. (2) Meningeal only—syndrome of Schultze (1880) which is the rarest. (3) Perineurial only—syndrome of Knoblauch (1843) which is the commonest.

2. Peripheral type. The peripheral neurofibromatosis of von Recklinghausen (1882) first described by Tilesius in 1793. The central and peripheral types may also occur in combination. The disorder appears to be closely related to epiloia.

Pathology.

The neurofibromas are tumours usually situated upon peripheral nerves and composed of bundles of long spindle cells. It has been stated that these tumours are derived from the cells of the sheath of Schwann, but it is more probable that they are formed from the *perineurial fibroblasts. They may also be found upon the cranial nerves,* most frequently upon the auditory nerve, but also upon others, especially the optic and trigeminal, and they may occur upon spinal nerve-roots, usually the posterior, or upon the cauda equina. The cutaneous fibromas, or mollusca fibrosa, are formed from the connective tissue elements of the cutaneous nerves. The bone changes associated with neurofibromatosis may consist *either of hyperostosis or of rarefaction,* with or without cyst formation. They have been variously explained and have even been regarded as a manifestation of osteomalacia. It is probable, however, that, as Parkes Weber suggests, they are a localized reaction of the bone to the growth of neurofibromas in the periosteum.

Neurofibromas may become sarcomatous. Abnormalities may be present in parts of the nervous system other than the peripheral *nerves.* Patches of gliosis and ependymal overgrowth may occur in

the brain and spinal cord, syringomyelia, and even rarely true tumours —glioma and ependymoma. Glioma of the optic chiasma may be associated with neurofibromatosis, and meningeal fibroblastomas are not uncommon. Neurofibromatosis is occasionally associated with other congenital abnormalities, such as spina bifida, cerebral meningocele, buphthalmos, syndactyly, and haemangiectatic naevi

Aetiology.

The disease appears to be due to a congenital abnormality of the ectoderm. It is hereditary, behaving in inheritance as a Mendelian dominant Some members of affected families may show only cutaneous pigmentation, while others exhibit a more extensive clinical picture. Bilateral acoustic neurofibromas sometimes occur in many members of a sibship in successive generations

Symptoms.

Some of the symptoms of neurofibromatosis are always present at birth, for example, cutaneous pigmentation. Others may be absent or may appear later, as a result of slow growth of the neurofibromas or of the reaction of other tissues to these tumours. In some cases, however, the disorder is little, if at all progressive, and may be discovered accidentally. Except in those cases in which gross congenital abnormalities are present, the patient does not usually come under observation on account of symptoms until after the age of 20.

Cutaneous Pigmentation

This is almost invariably present It consists of brownish spots, café-au-lait in colour, varying in size from a pin's head to areas the size of the palm. Occasionally a sheet of diffuse pigmentation may be present on one or both sides of the trunk, corresponding to the cutaneous distribution of several spinal segments. Cutaneous pigmentation is always most evident on the trunk and may be absent from the exposed parts (See Figs. 57 and 58.)

Cutaneous Fibromas

Cutaneous fibromas or mollusca fibrosa are soft, pinkish swellings, which may be sessile or pedunculated and vary in size from a pin's head to an orange. They are frequently present in large numbers and are situated chiefly upon the trunk, but some are usually to be found on the face.

Neurofibromas.

Neurofibromas are most readily discovered upon the superficial cutaneous nerves, especially those of the extremities and of the sides

of the neck. The tumours are to be felt as movable, bead-like nodules. They may give rise to pain and are occasionally tender on pressure.

Plexiform Neuroma.

'Plexiform neuroma' is the term applied to a diffuse neurofibromatosis of nerve-trunks, which is often associated with an overgrowth of the skin and subcutaneous tissues. In this way large folds of skin may be formed or there may be a diffuse enlargement of the subcutaneous tissues of a limb, with or without underlying bony abnormality The commonest sites are the temple, the upper lid, and the back of the neck. The cutaneous hyperplasia has received the names of dermatolysis, pachydermatocele, and elephantiasis neuromatosa. It is probable that the famous 'Elephant Man' described by Treves was an example of this disorder. A similar hyperplasia may occur in one half of the tongue and in the gums on one side.

Acoustic neurofibroma is described on p. 261.

Osseous Manifestations.

Kyphoscoliosis is frequently present in neurofibromatosis and may be so severe as to cause compression of the spinal cord. This occurred in the patient shown in Figs. 57 and 58. There may be marked hyperostosis of the bones of the face, with enlargement and rarefaction of the calvarium. These changes may be mainly unilateral. The long bones of the limbs may undergo subperiosteal hyperostosis, and the shaft may be curved.

Retinal Manifestations.

Phakomas, which are flat, white or grey, oval or circular masses, about half the size of the optic disk, may occur in the retina (van der Hoeve).

Visceral Neurofibromas.

Neurofibromas have been described on the mucous membranes and in various viscera, including the suprarenals. The vagus and sympathetic nerves may also be affected.

Complications.

Compression of the spinal cord may occur as a result of severe kyphoscoliosis or of a neurofibroma, or the scoliosis may lead to root pains Neurofibromas within the skull may give rise to symptoms of increased intracranial pressure and of focal compression of the brain. Intracranial glioma or meningioma may give rise to symptoms. A sarcomatous change in a neurofibroma manifests itself as a rapid
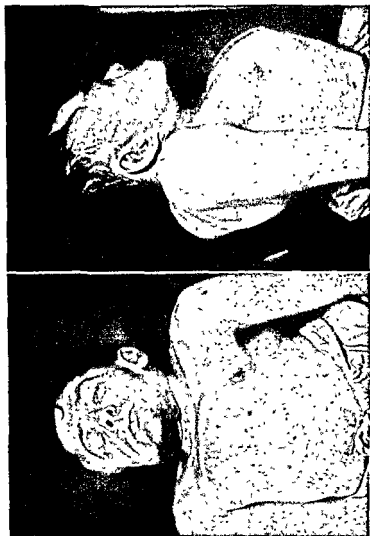
Figs. 57 and 58. A case of neurofibromatosis with cutaneous pigmentation, hyperostosis of the skull, right-sided lophthalmos, plexiform neuroma of the right side of the face, and kyphoscoliosis (elephantiasis neuromatosa)

increase in the size of the tumour, with compression and invasion of the neighbouring structures. Epilepsy, acromegaly, adipo-o-genital dystrophy, infantilism of the Lorain type, and Addison's disease have all been encountered as complications. Optic atrophy may occur.

Diagnosis.

The association of cutaneous pigmentation with neurofibromas and frequently with other associated abnormalities constitutes a unique clinical picture. Difficulties in diagnosis are likely to arise only when some of these clinical features are absent or inconspicuous. Thus a patient may come under observation presenting symptoms of an intracranial tumour, spinal compression, scoliosis with root pains, hyperostosis, or localized elephantiasis. A careful examination of the skin of the whole body for pigmentation, cutaneous and neural fibromas, will usually enable a correct diagnosis to be made.

Prognosis.

The disorder is not always progressive, but the presence of any symptoms in a child or adolescent should lead to a guarded prognosis, as the disorder may later reach its fully developed form. Pregnancy especially may lead to an exacerbation. Frequently the disease does not shorten life nor lead to marked discomfort. In severe cases death may occur from one of the complications described above, from tuberculosis, or after a terminal phase of cachexia.

Treatment.

Treatment is merely palliative. Painful subcutaneous neurofibromas may be treated by X-ray irradiation or by excision. Suitable operative treatment may be required for associated intracranial or intraspinal tumours, or when a peripheral neurofibroma becomes sarcomatous.

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7. THE HEREDITARY ATAXIAS

Definition: The term 'hereditary ataxia', though by no means completely descriptive, is a convenient one to apply to a group of closely related disorders, usually hereditary or familial, and characterized pathologically by degeneration of some or all of the following parts of the nervous system—the optic nerves, the cerebellum, the olives, and the long ascending and descending tracts of the spinal cord. These localized degenerations occur in various combinations, with corresponding symptoms. The age of onset ranges from childhood to middle life, and the course of the disease is slowly progressive A number of varieties have been described differing in the distribution of the symptoms Friedreich's ataxia is relatively common. Some forms of hereditary ataxia are confined to a single family. Each variety tends to breed true, but does not always do so, and more than one form may occur in the same family. The existence of transitional forms lends support to the view that all varieties are due to the same underlying abnormality, which varies in its incidence upon different parts of the nervous system. It is impossible to describe in detail all the forms of hereditary ataxia which have been reported. The following are the most important:

(1) Hereditary spastic paraplegia.
(2) Friedreich's ataxia.
(3) The variety described by Sanger-Brown.
(4) A form resembling disseminated sclerosis, of which Ferguson and Critchley have given a description.
(5) Marie's cerebellar ataxia.
(6) Various forms of progressive cerebellar degeneration.

Pathology.

The pathology of the different varieties of hereditary ataxia will be described in more detail in the appropriate sections. They present the following features in common.

There is a degeneration of the ectodermal elements of the nervous system The nerve-fibres are usually affected more severely than the ganglion cells, but in the later stages these also suffer, though it is difficult to say whether their degeneration is primary or secondary to the degeneration of their axones. The cerebellum and spinal cord

are usually smaller than normal and occasionally show evidence of congenital abnormalities. The brunt of the degenerative process usually falls either on the spinal cord or on the cerebellum. Exceptionally both are involved. In the spinal forms some degenerative changes are usually to be found in all the long ascending and descending tracts, though a predominant incidence upon certain tracts determines the nature of the clinical picture. Thus the pyra-

Fig. 59.   Friedreich's ataxia.   Spinal cord.

midal tracts are most affected in hereditary spastic paraplegia; the pyramidal tracts, the posterior columns, the dorsal spino-cerebellar tracts, and the ganglion cells of Clarke's column in Friedreich's ataxia (Fig 59); while the changes are most marked in the anterior columns in the cerebellar ataxias. Degeneration is manifest in loss of myelin and destruction of axones, with a reactionary gliosis.

Aetiology.

An inherited abnormality is the primary cause of the hereditary ataxias, but as in the case of other inherited disorders sporadic cases are not much less common than familial ones. Males and females are affected with approximately equal frequency, and the disease may be transmitted either by affected or by normal individuals. When it develops early in life it usually acts as a barrier to marriage in those individuals who survive to a marriageable age, and in such families transmission necessarily occurs more frequently through normal than

through affected individuals. The mode of inheritance of hereditary
ataxia cannot satisfactorily be explained on the assumption that the
disease behaves as a single Mendelian character, whether dominant
or recessive. The best interpretation of the available facts regarding
its transmission is that it depends upon the presence of two Mende-
lian characters, one of which is a dominant and the other a recessive.
Nothing is known as to the cause of the germinal mutation by which
it originates, but it has long been held that parental alcoholism may
cause the disease by damaging the germinal material. Acute infec-
tions have sometimes been regarded as precipitating factors. These
are so common that little importance can be attached to them,
though it is possible that they may accelerate degeneration in the
nervous system in an individual already predisposed to it by
heredity.

CLINICAL VARIETIES

HEREDITARY SPASTIC PARAPLEGIA

This disorder usually affects several siblings, with or without a
history of cases in previous generations Sporadic cases occur Males
suffer more frequently than females. The onset of symptoms is
usually in childhood, between the ages of 3 and 15 years, rarely in
middle age.

Pathology.

The maximal degeneration is found in the pyramidal tracts of the
spinal cord, especially from the upper dorsal region downwards.
This is associated with slighter degenerative changes in the posterior
columns, especially the column of Goll, and in the large pyramidal
cells of the precentral convolution.

Symptoms.

Symptoms are those of a progressive destruction of the pyramidal
tracts beginning in the lower limbs. Attention is first attracted to
the child on account of its stiff and clumsy gait. The lower limbs are
found to be weak and spastic, with exaggerated tendon reflexes and
extensor plantar responses. The abdominal reflexes are diminished
or lost and pes cavus is usually present. Later the upper limbs are
similarly affected, and finally the muscles innervated from the brain-
stem, with the production of spastic dysarthria and dysphagia and
loss of emotional control The sphincters are usually slightly affected
in the later stages. In spite of degeneration in the posterior columns,
no loss of superficial or deep sensibility can usually be detected.
Primary optic atrophy and retinal pigmentation have been de-
scribed. Mentality is usually normal.

Prognosis.

The disease runs a slowly progressive course, weakness and con-
tracture finally confining the patient to bed. Death occurs after
many years, usually from an intercurrent infection.

FRIEDREICH'S ATAXIA

The mode of inheritance of this disorder has already been discussed.
It is usually familial and hereditary, but sporadic cases occur. The
age of onset, interpreted as the age at which symptoms first bring
the patient under observation, is usually between 5 and 15 years,
though abnormalities such as pes cavus may be discovered in
apparently normal members of affected families in early childhood.
Exceptionally, symptoms first appear between the ages of 20 and 30,
rarely after 30.

Pathology.

The spinal cord is unusually small, but the cerebellum is usually
normal Histologically (Fig. 59) the degeneration is most marked
in the posterior columns, especially in Goll's tract. It is most intense
in the lower parts of the cord and diminishes towards the medulla.
Next to the posterior columns, the lateral columns suffer most,
especially the pyramidal tracts and the dorsal spino-cerebellar
tracts, together with the cells of Clarke's column, from which the
latter are derived. The ventral spino-cerebellar tracts usually escape.
There is a reactionary gliosis in the degenerated regions. The dorsal
*root-fibres also exhibit degeneration, though their ganglion cells
may be little affected.* Exceptionally there is some degeneration
of the anterior horn cells.

The heart may show a diffuse change, enlargement being caused
by thickening of the muscle and a diffuse fibrosis. Microscopically
there is fatty degeneration of the muscle fibres with slight chronic
inflammatory infiltration and fibrosis (D. S. Russell).

Symptoms.

As might be deduced from the pathological changes, the cardinal
symptoms of Friedreich's ataxia are: ataxia, most marked in the
lower limbs, with *signs of destruction of the pyramidal tracts, loss*
of deep reflexes, and, to a variable extent, impairment of sensibility,
especially deep sensibility. In addition, pes cavus and scoliosis are
present, and nystagmus and dysarthria indicate a disturbance of
cerebellar function at the level of the cranial nerves.

Symptoms appear first in the lower limbs, and it is the ataxic
gait which usually first attracts attention. The patient walks on
a broad base and tends to reel or stagger. In severe cases he is

unable to walk without support on both sides. Standing is similarly affected, and he sways and may be unable to stand without support. The unsteadiness of stance is not usually intensified by closing the eyes. Ataxia of the lower limbs is usually less evident in movement of the limbs individually when the patient is lying in bed. In the later stages movements of the upper limbs also become ataxic and intention-tremor is present. Slight involuntary movements, which have sometimes been described as choreiform or myoclonic, are often present in the later stages. These are probably the result of defective co-ordination. Irregular oscillations of the head are common. Nystagmus is present in 70 per cent. of cases, and it is usually most marked on lateral ocular deviation. Speech is invariably dysarthric in the later stages, the dysarthria being of the variety associated with cerebellar disease. Speech is usually slow, monotonous, and slurred, and may be explosive or scanning. It is frequently accompanied by vigorous grimaces and associated movements of the facial musculature. Pyramidal degeneration leads to weakness, most marked in the lower limbs, with loss of the abdominal reflexes and extensor plantar responses. The tendon reflexes tend to be lost owing to interruption of the reflex arcs on the afferent side. The ankle-jerks are lost before the knee-jerks, and the latter may be exaggerated, owing to the pyramidal lesion, when the former are diminished. The limbs may be either hypotonic or slightly spastic, depending upon the relative severity of loss of afferent impulses from the muscles, which tends to diminish muscle-tone, and of the pyramidal lesion, which tends to increase it. Sensory changes are inconstant and may be absent Shooting pains occasionally occur in the limbs. Postural sense and appreciation of passive movement are not infrequently impaired, especially in the lower limbs. In some cases all forms of sensibility are affected. The sphincters are usually unaffected, though incontinence of urine, and more rarely of faeces, may occur in the late stages Pes cavus and scoliosis are present in almost all cases, the former being usually associated with a slight contracture of the muscles of the calf. Pes cavus is usually attributed to occurrence of pyramidal degeneration at an early age, and the scoliosis is probably due to interruption of afferent impulses regulating posture from the spinal muscles. Some authorities, however, hold that pes cavus is a congenital bony abnormality which is independent of the disease of the nervous system.

Optic atrophy occasionally occurs, and retinal pigmentation has been described. Other rare ocular symptoms include ptosis, abnormalities of the pupillary reflexes, and ophthalmoplegia Deafness sometimes occurs. Muscular atrophy is a rare complication and is most frequently seen in the hands, leading to claw-hand.

Associated congenital abnormalities include spina bifida occulta and infantilism.

The mental condition of sufferers from Friedreich's ataxia is frequently normal, but a mild dementia is not uncommon in the later stages, leading to impaired intelligence and irritability. The cerebro-spinal fluid is normal.

Prognosis.

Friedreich's disease is in most cases slowly but steadily progressive. Occasionally, however, it appears to become arrested, and abortive cases are encountered, for example as accidental discoveries in apparently healthy members of affected families, in whom the disorder does not progress. Few patients, however, live for more than twenty years after the onset of symptoms, and death usually occurs from an intercurrent infection or from heart failure.

SANGER-BROWN'S ATAXIA

Sanger-Brown in 1892 described a variety of hereditary ataxia affecting twenty-four individuals in five successive generations of the same family Pathological examination showed degeneration of the cells of Clarke's column, of the posterior columns, and of the dorsal spino-cerebellar tracts. There was little or no pyramidal degeneration, and changes in the cerebellum were slight or absent.

The age of onset lay between 16 and 35 years, the first symptom being ataxia of the lower limbs. The condition differed from Friedreich's ataxia in the presence of optic atrophy, ptosis, diplopia, and, occasionally, of complete internal and external ophthalmoplegia, and of exaggerated tendon reflexes and ankle clonus, whereas nystagmus and pes cavus were absent.

A very similar disorder was reported by Neff in four generations of a single family, thirteen individuals being affected. This disorder differed from the ataxia of Sanger-Brown in that the onset of symptoms was delayed until between the ages of 50 and 65, and in some cases even later. Four affected members of Neff's family developed dementia

HEREDITARY ATAXIA RESEMBLING DISSEMINATED SCLEROSIS

Ferguson and Critchley have described the clinical features of a form of hereditary ataxia resembling disseminated sclerosis and not infrequently mistaken for it. Sixteen cases occurred in three successive generations. The usual age of onset was between 30 and 45, and both sexes were affected. As in disseminated sclerosis mild mental changes consisting of euphoria and emotional instability were common. Slight optic atrophy was observed in some cases, and

external ophthalmoplegia, especially weakness of upward deviation of the eyes, was frequently present. Nystagmus was also observed. Most patients exhibited signs of bilateral pyramidal degeneration, especially extensor plantar responses, but in several the tendon *reflexes were diminished or lost. Cerebellar inco-ordination in the* limbs with dysarthria and an ataxic gait were present, together with tremor and not uncommonly a Parkinsonian facies. Extensive areas of relative analgesia and anaesthesia were usually found, but deep *sensibility was less affected. Some disturbance of sphincter control* was common. Pes cavus and scoliosis were observed in only two cases. The course of the disorder was progressive without remissions. In some cases death occurred within ten years of the onset of symp*toms. Other members of the family were still alive after a longer* period.

HEREDITARY CEREBELLAR ATAXIA OF MARIE

Marie, in 1893, under the title of 'hereditary cerebellar ataxia', described a group of patients suffering from signs of cerebellar deficiency and pyramidal degeneration with, in some cases, optic atrophy The onset of symptoms occurred during adolescence, and multiple cases were observed in the same family. Pathological examination of cases exhibiting the clinical features described by Marie has usually shown a slight degree of atrophy of the cerebellum, while in the spinal cord degeneration was most marked in the ascending cerebellar tracts and the antero-lateral columns, the pyramidal tracts and posterior columns being little affected. It is doubtful, however, whether this form of cerebellar ataxia can be considered either a clinical or a pathological entity. It is probably a mixed group containing some cases of Friedreich's ataxia together with cases allied to the Sanger-Brown variety.

PROGRESSIVE CEREBELLAR DEGENERATION

Although not all forms of progressive cerebellar degeneration have been shown to be familial or hereditary, they exhibit a sufficient clinical and pathological similarity to justify their consideration together. The following are the more important varieties that have been described:

Primary parenchymatous degeneration of the cerebellum (Holmes).
Olivo-ponto-cerebellar atrophy (Dejerine and Thomas).
Olivo-rubro-cerebellar atrophy (Lhermitte and Lejonne).
Delayed cortical cerebellar atrophy (Rossi, Marie, Foix, and Alajouanine).

As their names imply, these forms of cerebellar degeneration differ in the precise localization of the degenerative process and its incidence

upon the brain-stem. They are probably, however, mutually related in the same way as Friedreich's ataxia, Sanger-Brown's ataxia, and hereditary spastic paraplegia.

Primary Parenchymatous Degeneration of the Cerebellum.

Under this title Holmes has described four cases occurring in a single family. One case was investigated pathologically. The cerebellum, pons, and medulla were abnormally small, especially the cerebellum, which on microscopical examination showed atrophy of all three cortical layers. This was associated with atrophy and gliosis of the olives and of the olivo-cerebellar fibres in the medulla and restiform body. The midbrain, pons, and spinal cord were normal. The symptoms, the onset of which occurred in early middle life, between the ages of 33 and 40, were those of progressive cerebellar deficiency. Speech became explosive, and nystagmus and ataxia of the upper and lower limbs were present. Vision and the optic nerves were normal, the tendon reflexes were brisk and there was no sensory disturbance.

Olivo-ponto-cerebellar Atrophy.

This form of cerebellar atrophy was described by Dejerine and Thomas in 1900. It is only exceptionally familial, in most cases being sporadic

The pathological changes consist of atrophy of the ganglion cells of the olives, and of the grey matter of the pons, with degeneration of the middle cerebellar peduncles and to a less extent of the restiform bodies The cerebellum suffers mainly as a result of atrophy of its afferent fibres by these routes. The Purkinje and other ganglion cells of the cerebellar cortex are affected secondarily. It is the neo-olive and the neo-cerebellum which undergo degeneration. The central nuclei of the cerebellum are relatively unaffected, but in *olivo-rubro-cerebellar atrophy* these degenerate, together with the superior peduncles, and degeneration can be traced as far as the red nuclei.

The onset of symptoms occurs in late middle life up to the age of 60 The symptoms are those of a slowly progressive cerebellar deficiency, namely, dysarthria, ataxia and tremor of the limbs, ataxic gait, and muscular hypotonia. Nystagmus is usually absent. Voluntary power is well preserved and the reflexes are usually normal, except that the ankle-jerks may be lost. Mental deterioration may occur in the later stages.

Delayed Cortical Cerebellar Atrophy.

This disorder occurs sporadically, but Critchley has raised the question of its possible relationship to familial tremor, there being

some evidence that the two disorders may occur in the same family. Males are affected more often than females.

The degenerative process involves the ganglion cells of the cerebellar cortex especially those of the antero-superior aspect of the vermis and the anterior part of the quadrilateral lobe of the cerebellum, and a portion of the olives may be affected (Critchley).

The onset of symptoms occurs in late middle life, usually about the age of 60. The first symptom is usually a slowly progressive ataxia of the gait, which may precede other symptoms by months or even by years and is in conspicuous contrast with the absence of inco-ordination of movements of the lower limbs when the patient is lying down. Later, signs of cerebellar deficiency, including inco-ordination and intention-tremor, are present in the upper limbs, and speech becomes slow and slurred and sometimes scanning. Nystagmus is usually absent. The limbs may be somewhat hypotonic, but not uncommonly muscle-tone is normal. The reflexes are frequently normal, but the ankle-jerks may be lost, and bilateral extensor plantar responses are not uncommon. The disease is steadily progressive.

Diagnosis.

The diagnosis of the hereditary ataxias rests upon the onset, in most cases before the age of 20, of progressive symptoms, of which ataxia is usually the most conspicuous, and which frequently include symptoms of bilateral pyramidal degeneration, sensory loss, pes cavus and scoliosis, and sometimes optic atrophy. *When the disorder is familial or hereditary* and the history of its incidence can be obtained it is usually easy to make a correct diagnosis. Sporadic cases, however, may give rise to difficulty. Hereditary spastic paraplegia must be distinguished from congenital diplegia by the facts that the patient is normal at birth and that the disorder is progressive, whereas in diplegia the symptoms are congenital and tend to improve and are not uncommonly associated with mental deficiency and with epilepsy. Friedreich's ataxia must be distinguished from disseminated sclerosis and from tabes. It frequently begins before the age of 15, when the onset of disseminated sclerosis is rare. Both disorders are characterized by nystagmus, ataxia, and extensor plantar responses, but scoliosis, pes cavus, and loss of the knee- and ankle-jerks are peculiar to Friedreich's disease. The distinction of Friedreich's disease from tabes is based upon the absence in the latter of pes cavus, scoliosis, dysarthria, and extensor plantar responses, and the presence of Argyll Robertson pupils and, in most cases, of a positive Wassermann reaction in the blood and cerebrospinal fluid. The diagnosis of a sporadic case of the ataxia described by Ferguson and Critchley from disseminated sclerosis may be

extremely difficult, if not impossible. The most helpful points of
distinction are the occurrence in the ataxia of external ophthalmo-
plegia, especially weakness of upward deviation of the eyes and the
absence of the remissions so characteristic of disseminated sclerosis.

The progressive cerebellar degenerations of late middle life are
to be distinguished from vascular lesions of the cerebellum, by their
slow onset and progressive course; from tumours, by the absence of
increased intracranial pressure; from tabes, by the usual preservation
of the tendon reflexes, by the absence of sensory loss and of pupillary
abnormalities; and from subacute combined degeneration, by the
absence of paraesthesiae, sensory loss, and gastric achylia.

Treatment.

No treatment which can influence the course of the degeneration
is known. Although the patient will ultimately become bedridden,
this should be postponed as long as possible. Re-educational
exercises may do much to keep the ataxia under control. In Fried-
reich's ataxia the pes cavus may require surgical treatment or
appropriate boots. In the later stages care must be taken to avoid
as far as possible exposing the patient to the risk of infections of the
respiratory tract.

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8. AMYOTROPHIC LATERAL SCLEROSIS

Synonyms: Progressive muscular atrophy; progressive bulbar palsy; motor neurone disease; chronic poliomyelitis.

Definition: A disease characterized pathologically by degenerative changes, which are most marked in the anterior horn cells of the spinal cord, the motor nuclei of the medulla, and the pyramidal tracts, and clinically by progressive wasting of the muscles, especially those of the upper limbs and those innervated from the medulla, combined with symptoms of pyramidal degeneration. The term 'progressive muscular atrophy' is associated especially with the names of Aran (1850) and Duchenne (1847). Charcot (1869) distinguished two varieties—progressive muscular atrophy of Aran and Duchenne, characterized only by lower motor neurone lesions, and a form in which these were associated with symptoms of pyramidal lesions and which he called 'amyotrophic lateral sclerosis'. These two varieties are now usually regarded as nosologically identical. When the lower motor neurone lesions predominate, or, as more rarely happens, occur alone, the term 'progressive muscular atrophy' is still sometimes applied to the disease, and when the muscles innervated from the medulla are predominantly involved it has been termed 'progressive bulbar palsy'. In most cases, however, the symptoms of upper and lower motor neurone lesions are mixed, except in the lower limbs, where the latter are frequently absent until the terminal stages.

Pathology.

The Spinal Cord.

Naked-eye changes in the spinal cord are slight, but on section the grey matter of the anterior horns appears smaller than normal and the anterior roots are wasted. Microscopically there is severe degeneration of the ganglion cells of the anterior horns. This change is usually most marked in the cervical enlargement of the cord, but is

FIG. 60. Amyotrophic lateral sclerosis. Spinal cord, L 1.

always widespread, and its severity is not invariably proportional to the clinical condition. The ganglion cells exhibit chromatolysis, which is at first perinuclear. The neurofibrils disappear, and there is frequently a granular deposit of lipochrome. The total number of ganglion cells is much reduced. As a rule all groups within the anterior horn suffer equally. There are exceptions to this, however, but there is no general agreement as to whether some are more susceptible than others. *The degeneration is associated with a slight* secondary gliosis, and occasionally slight perivascular infiltration with round cells has been observed.

The Weigert-Pal stain reveals degeneration of the white matter of the spinal cord, which is most marked in, and often confined to, the antero-lateral columns (Fig. 60). The pyramidal fibres suffer most, both the direct and the crossed pyramidal tracts being affected. Pyramidal degeneration is never equally severe at all levels. It is not uncommon to find an advanced change in the lower dorsal and

lumbo-sacral regions, while the upper dorsal region is but slightly affected, and severe changes are found again in the cervical enlargement, extending up to the medulla. The spino-cerebellar tracts usually show degeneration, especially the anterior, and the severity of this change varies in different segments. The rubro-spinal, vestibulospinal, and tecto-spinal tracts are also degenerated to a variable extent, and slight degeneration is occasionally present in the posterior columns. The endogenous fibres of the spinal cord which lie close to the grey matter are degenerated in the antero-lateral columns, but not in the posterior columns.

The Medulla.

The ganglion cells of the medullary motor nuclei show degenerative changes which are in all respects similar to those of the anterior horn cells of the spinal cord. These alterations are most marked in the hypoglossal nucleus, the dorsal nucleus of the vagus, the nucleus ambiguus, and the trigeminal motor nucleus. The facial nucleus is usually less severely affected. Similar changes have been observed in the sensory nuclei. There is a marked degeneration in the pyramids of the medulla. Bertrand and van Bogaert have described a case in which pyramidal degeneration was severe in the medulla and negligible in the pons and cerebral peduncles. Degeneration has also been described in the restiform body, the posterior longitudinal bundle, the median and lateral fillets, and the reticular formation The third and fourth nerve nuclei in the midbrain almost invariably escape.

The Cerebral Hemispheres.

Naked-eye changes are usually inconspicuous, but slight atrophy of the ascending frontal convolutions has been described. Microscopical changes are most marked in the cerebral cortex anterior to the fissure of Rolando. The typical lesion in subacute cases is a lipochrome degeneration of the ganglion cells in the frontal and precentral regions. This change is most marked in the third and fifth cortical layers, the latter of which contains the large pyramidal motor cells of Betz, from which the pyramidal tracts take origin. Degeneration has also been observed in the tangential fibres of the cortex. Some glial overgrowth is usually present in the regions which are the site of atrophy. Degenerative changes are also found in the middle-third of the corpus callosum and in the pyramidal fibres in the posterior limb of the internal capsule.

Peripheral Nerves and Muscles.

The anterior roots and peripheral nerves exhibit degeneration, with atrophy of the myelin sheaths. The muscles show atrophy of

the contractile substance with persistence of striation and prolifera-
tion of the sarcolemmar nuclei.

Aetiology.

Amyotrophic lateral sclerosis is a disease of early middle life,
usually beginning between the ages of 35 and 50, occasionally as
late as 70. It is very rare in early life, but it has been known to
occur in childhood, usually during the second decade. Most cases are
sporadic, but familial occurrence, though very rare, is not unknown,
and in such cases the onset may occur either in middle life or in
childhood. Males are affected more often than females in the propor-
tion of three to one.

*Although in exceptional cases the disease may be due to an in-
herited predisposition to degeneration of the motor neurones, there*
is no reason to believe that this cause operates as a rule. It has been
regarded by some workers as inflammatory, and hence has been
called 'chronic poliomyelitis', but this hypothesis is not borne out by
the histological appearances. Inflammatory infiltration is rare and
scanty, and when it occurs probably should be regarded as a reaction
to degeneration. Most authorities regard amyotrophic lateral sclero-
sis as due to a toxin which possesses a predilection for the anterior
horn cells. Bertrand and van Bogaert make the interesting sugges-
tion that the primary disturbance is damage to the grey matter of
the spinal cord, the process spreading across the synapses to involve
the endogenous association fibres and the pyramidal fibres. This
hypothesis affords an explanation of the patchy segmental distribu-
tion of the pyramidal degeneration, which on this account can hardly
be regarded as secondary to degeneration of the Betz cells of the
motor cortex. If the disease is indeed toxic in origin, the nature of
the toxin is in most cases unknown. *Exceptionally, the condition*
follows lead poisoning, and syphilis is regarded by some writers as
responsible for a proportion of cases. Syphilitic amyotrophy, how-
ever, is usually clinically distinguishable from amyotrophic lateral
sclerosis, and the remaining cases in which the latter condition is
associated with a positive Wassermann reaction in the blood or cere-
bro-spinal fluid are few. Exceptionally, amyotrophic lateral sclerosis
has been observed to supervene in an individual who many years
previously suffered from acute anterior poliomyelitis. This associa-
tion is so rare that it may be coincidental. It is conceivable, however,
that the intoxication of the anterior horn cells due to acute polio-
myelitis may render them liable to degenerate later if exposed to
other toxins. There is no conclusive evidence that trauma plays any
*part in aetiology, but it is an old observation that weakness and
wasting may first appear in the muscles which are most used by the*

patient in his occupation. It is unlikely, however, that fatigue is a cause of the disease, though it may determine the site of onset

Symptoms.

Mode of Onset.

The disease is usually chronic, but may run a subacute course Correspondingly the onset is generally insidious, but may be more rapid. The nature of the earliest symptoms depends upon which region of the nervous system is first affected. Commonly the first abnormality is observed in the hands, where the patient may be conscious of weakness, stiffness, or clumsiness of movements of the fingers, or his attention may be drawn to the wasting, or he may perceive fibrillary twitching. When the shoulder girdle and upper arm muscles are first affected the first symptom is weakness of movements of the shoulder. When degeneration begins in the bulbar motor nuclei the first symptom to be noticed may be dysarthria or fibrillation of the lips or tongue Less frequently weakness and stiffness of the lower limbs occur early, and cramp-like pains in the limbs are often an early symptom.

Symptoms of Lower Motor Neurone Degeneration.

Degeneration of the anterior horn cells and of the motor cells of the medulla leads to weakness and wasting of the muscles which they innervate. Fibrillation is also a conspicuous symptom and occurs in those muscles which are supplied by ganglion cells undergoing active degeneration. It may be limited to a few groups of muscles, or much more widespread, and its extent is an indication of the diffuseness of the degenerative process. Very rarely widespread weakness and wasting may occur in the absence of fibrillation. When fibrillation is not immediately evident it can often be evoked by sharply tapping the muscle. Contractures are usually slight As a rule muscular wasting begins in the hands, the muscles of the thenar eminences being first affected Not uncommonly one hand may begin to waste some months or even a year before the other. In other cases the onset is symmetrical. The wasting tends to spread to the muscles innervated by the segment of the spinal cord adjacent to that first affected Hence, after the hands the forearm muscles are involved, the flexors usually suffering before the extensors. The weakness and atrophy of the hand muscles lead to clumsiness of the finger movements, and some degree of claw-hand usually develops (Figs. 61 and 62). This deformity is not, however, as a rule severe, since the long flexors and extensors of the fingers, by which it is maintained, are soon themselves affected.

Next in frequency the muscles of the shoulder girdle and upper arm are first involved, those innervated by the fifth cervical spinal segment, especially the deltoids, being earliest affected. Those

FIGS. 61 and 62. A case of amyotrophic lateral sclerosis. Wasting of the muscles of the hand. Note the prominence of the flexor tendons in the palm.

supplied by the sixth cervical segment, namely, the triceps, latissimus dorsi, the sternal part of the pectoralis major and serratus magnus, are usually involved much later, and the upper part of the trapezius also escapes until a late stage. The muscles innervated by the medulla may be the first to suffer or they may be affected simultaneously with, or shortly after, the upper limbs. The tongue is usually the first to waste and becomes shrunken and wrinkled and shows conspicuous fibrillation (Fig. 63). The orbicularis oris also suffers early, but the

orbicularis oculi and other facial muscles are affected later and less
severely. It has been suggested that the orbicularis oris may be
innervated by part of the hypoglossal nucleus, fibres from which

Fig. 63. A case of amyotrophic lateral sclerosis.
Wasting of the tongue.

join the facial nerve, and its affection *pari passu* with the tongue
has been thus explained. Functionally the lips and tongue are closely
related, but doubt has been cast upon the anatomical association of
the nuclei. The palate is usually involved shortly after the tongue,
together with the extrinsic muscles of the pharynx and larynx. The
intrinsic laryngeal muscles usually escape until late. The mandibular
muscles usually suffer less severely than the tongue and orbicularis
oris. Owing to weakness of the muscles concerned, pursing of the
lips and whistling become impossible, and in the later stages saliva
runs from the open lips. Protrusion of the tongue is at first weak

and later lost. Speech suffers from paresis of the lips, tongue, and palate. The capacity to pronounce labials and dentals is early impaired, and later gutturals. Speech becomes slurred and finally unintelligible. Phonation, however, suffers late, if at all. Swallowing becomes increasingly difficult, and food tends to regurgitate through the nose. Patients usually find semi-solids easier to swallow than either solids or fluids.

Exceptionally the extensor muscles of the cervical spine suffer early, and when this occurs the head falls forwards. Early involvement of the muscles of the lower limbs is rare. The anterior tibial group and peronei are usually first affected and bilateral foot-drop results. This mode of onset may closely simulate polyneuritis, especially when, as occasionally happens, the motor symptoms are associated with muscular pain and a slight degree of sensory loss. It has, therefore, sometimes been called the 'pseudo-polyneuritic' form.

In whatever part of the body muscular wasting begins, in most cases it sooner or later becomes generalized, though progressive bulbar palsy may prove fatal before wasting has had time to develop to a severe extent elsewhere. In the final stages weakness of the trunk muscles renders it impossible for the patient to sit up in bed, and paralysis of the respiratory muscles leads to increasing dyspnoea.

Electrical Reactions.

Owing to the fact that in a single muscle varying degrees of degeneration are usually present in different fibres, the electrical reactions of the muscles differ from those of simple degeneration following section of a motor nerve. The response to faradism is often little affected up to a late stage, but a normal, or almost normal, faradic response may be associated with the phenomenon of polar reversal when the galvanic current is used for stimulation. This combination has been termed 'a mixed reaction'.

Symptoms of Upper Motor Neurone Degeneration.

Save in those rare cases in which the degeneration is confined to the lower motor neurones the clinical picture is complicated by the symptoms of the upper motor neurone lesions which may be present from the beginning or may develop after muscular wasting. Since lower motor neurone lesions are rarely present at an early stage in the lower limbs, these usually for a long time present an uncomplicated picture of pyramidal degeneration, with weakness and spasticity, which rarely become severe. In the upper limbs the effects of the addition of an upper to a lower motor neurone lesion is to cause a degree of weakness which is disproportionately great in comparison with the severity and extent of the wasting, and the

tendon reflexes are exaggerated in spite of the wasting. It is in the muscles innervated from the medulla that the effects of pyramidal degeneration are of the greatest importance. Here we may encounter lower motor neurone degeneration only—progressive bulbar palsy, upper motor neurone degeneration only—'pseudo-bulbar palsy'; or a combination of the two, which is the most frequent occurrence. A lesion of both pyramidal tracts above the medulla, so-called 'pseudo-bulbar palsy', causes weakness of the bulbar muscles and hence leads to dysarthria and dysphagia. The paretic or paralysed muscles are not wasted and hypotonic, as in progressive bulbar palsy, but spastic. The tongue may appear somewhat smaller than normal on account of the spastic contraction of its muscles, but is not wrinkled and exhibits no fibrillation. The jaw-jerk, palatal and pharyngeal reflexes are exaggerated and sneezing and coughing may be excited reflexly with abnormal readiness. The dysarthria resembles that which results from a lower motor neurone lesion of the muscles of articulation. Pseudo-bulbar palsy, when severe, also leads to an impairment of voluntary control over emotional reactions, as a result of which paroxysmal attacks of involuntary laughing and crying occur. These may take the form of an exaggeration or a prolongation of a normal emotional response. Thus a patient laughs because he is amused, but having begun to laugh, is unable to stop. On the other hand, the emotional response may be quite inappropriate, such as uncontrollable laughter on hearing bad news, and then fails to correspond to, or express, the patient's emotional state. When pseudo-bulbar palsy and progressive bulbar palsy are associated in the same individual, dysarthria and dysphagia are intensified, impairment of emotional control may be present, and an exaggerated jaw-jerk is obtained, in spite of manifest wasting of the bulbar muscles.

The Reflexes.

The condition of the reflexes in a given case depends upon the relative preponderance of upper and lower motor neurone degeneration. The palatal and pharyngeal reflexes tend to be lost in the later stages owing to interruption of the reflex arcs concerned. Owing to the presence of pyramidal degeneration the abdominal reflexes are usually diminished or lost and the plantar reflexes extensor. The deep reflexes, that is, the jaw-jerk and the tendon reflexes of the limbs, vary between exaggeration and abolition. Degeneration of the lower motor neurones causes impairment, and finally loss, of the reflexes effected by the muscles innervated. Pyramidal degeneration, however, leads to exaggeration of the deep reflexes. Hence it is not uncommon to find exaggerated tendon-jerks in the upper limbs in

spite of considerable muscular atrophy, an association which led to the term 'tonic muscular atrophy' being applied to such cases. Since in the lower limbs muscular wasting is usually late in developing, the knee- and ankle-jerks are exaggerated.

Other Symptoms.

In the early stages the sphincters are not as a rule severely affected, though slight precipitancy or difficulty of micturition is not uncommon Later retention or incontinence may occur. Impotence often develops early.

When the sympathetic ganglion cells in the lateral horns of the grey matter of the upper dorsal region undergo degeneration, symptoms of oculo-sympathetic paralysis, slight ptosis, enophthalmos, and contracted pupils will be present.

Sensory changes are uncommon, except the occurrence of pain in the early stages, which has already been mentioned. Impairment of cutaneous sensibility, and even of deep sensibility, however, occasionally occurs. The subcutaneous fat tends to disappear *pari passu* with the muscular wasting, and marked emaciation characterizes the later stages. Mental changes are absent and, although psychosis has occasionally been described, this is probably a coincidence or merely the reaction to a serious and disabling disease. Impairment of emotional control is a disorder of emotional expression and not of the underlying mental state.

Diagnosis.

Amyotrophic lateral sclerosis requires to be distinguished from other conditions leading to muscular wasting, especially in the upper limbs, and from other causes of bulbar palsy.

In syringomyelia muscular wasting of the upper limbs is associated with spastic weakness of the lower limbs. Fibrillation, however, is rarely observed in the wasted muscles, and the characteristic dissociated sensory loss, if not present at the outset, develops at an early stage.

In syphilitic amyotrophy the onset of the weakness and wasting is not infrequently accompanied by pain of considerable severity and of radicular distribution. Signs of pyramidal degeneration are usually lacking; pupillary abnormalities may be present; the Wassermann reaction is usually positive in either the blood or the cerebrospinal fluid, in which also other abnormalities characteristic of syphilis may be found.

Tumour of the spinal cord involving the cervical enlargement is likely to cause muscular wasting in one or both upper limbs, together with spastic paraplegia, but sensory loss is rarely absent and the

changes characteristic of spinal block are usually to be found in the cerebro-spinal fluid.

Inflammation of a spinal nerve, sometimes called radiculitis, causes wasting and weakness of the muscles which it supplies. The fifth cervical nerve is that most frequently affected. The onset is usually acute and associated with considerable pain in the neck and shoulder. The condition is not progressive, and any change is in the direction of improvement.

Cervical rib may be confused with progressive muscular atrophy, especially when it is bilateral, owing to the presence of wasting of the small muscles of both hands. Muscular fibrillation, however, is absent, and pain along the ulnar border of the hand and forearm is usually a prominent symptom, being frequently associated with relative anaesthesia and analgesia in this region. Moreover, cervical rib can be demonstrated radiographically, though it must be remembered that it is a common abnormality and may not be responsible for the symptoms of a patient in whom it is discovered.

Lesions of peripheral nerves give rise to little difficulty as a rule, since the distribution of the muscular wasting is at once recognizable as corresponding to the supply of the nerve, and in the case of the median and ulnar nerves is associated with sensory abnormalities possessing an equally distinctive distribution.

The muscular dystrophies also are unlikely to be confused with amyotrophic lateral sclerosis, since they usually develop at a much earlier age. Myotonia atrophica, however, is a disorder of adult life, but this condition is readily distinguished on account of the peculiar distribution of the wasting, with its predilection for the sterno-mastoids and the quadriceps, the presence of myotonia, the absence of fibrillation, and the association with cataract either in the patient or his ancestors.

Peroneal muscular atrophy is distinguished by the peculiar distribution of the wasting, which begins in the periphery of the limbs, but in the lower before the upper, and is associated with sensory loss. This disease, moreover, is usually familial, and the first symptoms generally appear in childhood.

Arthritis of the hands and fingers generally leads to considerable wasting of the muscles of the hands. The history of pain in the joints and the presence of articular or periarticular swelling, with limitation of joint movement, render the correct diagnosis easy.

Pseudo-bulbar palsy may be due to vascular lesions involving the pyramidal tracts at any point above the medulla. When these are sudden in onset the condition is unlikely to be confused with amyotrophic lateral sclerosis. When the onset is insidious, the

distinction must be based upon the absence of muscular wasting and the presence of arterial degeneration.

In syringobulbia the presence of the characteristic *dissociated* sensory loss over the face is a distinctive feature.

Prognosis.

Amyotrophic lateral sclerosis is a progressive disease, but its rate of progress shows considerable variations. In the minority of cases the patient goes rapidly downhill, muscular weakness, wasting, and fibrillation early becoming widespread, and death may occur within a year. In the cases in which the onset is slower the prognosis is influenced by several factors. Those in which the degeneration is for a long time confined to the lower motor neurones do best. Early involvement of the bulbar muscles makes the outlook worse, especially when progressive bulbar palsy is combined with pseudo-bulbar palsy. The average duration of life in the more chronic cases is several years: survival for five years is not rare, and exceptionally life may be prolonged for ten years or even longer. Temporary remissions may occur, during which for a time the disease ceases to progress. The generalization of fibrillation is a bad sign.

Treatment.

The cause of the disease being in most cases undiscoverable, treatment is limited to dealing with symptoms. Every effort should be made, however, to ascertain whether the patient has been exposed to any form of chronic intoxication. Syphilis should be excluded by the usual serological tests. The urine should be examined for the presence of lead, and inquiry should be made into the details of the patient's occupation, in case this may involve exposure to toxic substances. Focal sepsis should also be sought and treated. The patient should avoid fatigue and exposure to cold, but should be encouraged to continue at a light occupation as long as possible. Massage is advisable, if only for its psychological effects, but electrical treatment, especially faradism, probably does harm. When the disorder begins at the climacteric ovarian follicular hormone or testicular hormone may be given. For many years strychnine has been given, but is probably valueless. Mercury and iodide may be tried. In the later stages the bladder and skin may require the attention necessitated in cases of paraplegia.

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9. SPASTIC PSEUDO-SCLEROSIS

The term *spastic pseudo-sclerosis* was first applied by Jakob (1921) to a group of cases described by Creutzfeld (1920) and himself, in which mental deterioration was associated with symptoms of both pyramidal and extrapyramidal disease. It is convenient for the present to retain it for this group, though as the work of Lhermitte and McAlpine (1926) and Davison (1932) shows it is not certain that it corresponds to a nosological entity

Pathologically Davison found atrophy of the cerebral convolutions from the frontal to the parietal regions, with scantiness and destruction of the ganglion cells, especially in the third, fifth, and sixth layers, with marked destruction of Betz cells, proliferation of vessels, increase of microglia and protoplasmatic astrocytes of the cortical grey matter, demyelination of the pallidal fibres, destruction of the cells of the pallidum, the Corpus Luysii and the paraventricular nuclei and degeneration of the pyramidal tracts and of the anterior horn cells of the spinal cord. The cause of these changes is unknown.

Clinically the course of the disease is usually rapid, the patient surviving only for two or three years The symptoms are progressive dementia, dysarthria, spastic weakness of the limbs, extrapyramidal symptoms, such as rigidity of the Parkinsonian type, tremor or athetosis, and muscular wasting Neither mental changes nor muscular wasting, however, were present in Lhermitte and McAlpine's cases.

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10. PERONEAL MUSCULAR ATROPHY

Synonyms: Neural progressive muscular atrophy; Charcot-Marie-Tooth's disease.

Definition: A hereditary form of progressive muscular atrophy first described in 1886 by Charcot and Marie and later in the same year by Tooth. Wasting usually begins in the small muscles of the feet and later in those of the hands, and never advances beyond the peripheral parts of the limbs. The muscular atrophy is secondary to degeneration of the motor nerves, though whether this begins in the nerves or in the spinal cord is uncertain.

Pathology.

According to Buzzard and Greenfield the most constant pathological change is an interstitial neuritis of branches of the external popliteal nerve. In most cases, though not invariably, changes are also found in the spinal cord, especially degeneration of the ganglion cells of the anterior horns in the cervical and lumbar enlargements and of the cells of Clarke's column, together with degeneration of the dorsal columns and later of the pyramidal tracts. The affected muscles exhibit a simple atrophy. It appears likely that the changes in the spinal cord are secondary to the affection of the peripheral nerves, though involvement of the pyramidal fibres is difficult to explain on this hypothesis, unless, as has been suggested, in the case of amyotrophic lateral sclerosis, toxic substances have the power to pass from the anterior horn cells to the terminations of the pyramidal fibres.

Aetiology.

Although sporadic cases occur, the disease is usually hereditary and a number of pedigrees of affected families have been published.

Herringham has reported one in which 20 cases occurred in the course of five generations, the disease being transmitted as a sex-linked recessive, males only being affected. In the majority of affected families, however, it has behaved as a Mendelian dominant, affecting, and being transmitted by, both sexes. Males are affected more frequently than females, possibly on account of the occurrence of families with a sex-linked transmission. *Apart from the existence of inherited predisposition, little is known concerning the aetiology, though Petto has suggested that exogenous factors may also play a part in causation.*

In most cases the onset of symptoms occurs during the second half of the first decade of life, but has been known to occur up to the age of 40.

Symptoms.

The first symptoms are muscular wasting and weakness, which usually begin in the peronei, extensor communis digitorum, or the small muscles of the foot, symmetrically on the two sides. Paralysis of the peronei leads to talipes equino-varus, but when the wasting begins in the intrinsic muscles of the feet pes cavus results. Not uncommonly it is the deformity of the feet and the resulting laborious 'steppage' gait which bring the patient under observation. Wasting does not usually appear in the hands until a number of years after its onset in the feet. Occasionally, however, both upper and lower extremities are affected simultaneously; exceptionally the hands suffer first. The muscular atrophy, which is not uncommonly associated with fibrillation, tends to spread very slowly proximally, not involving the muscles longitudinally but transversely. It does not extend above the elbows nor above the junction of the middle and lower thirds of the thigh. This peculiar ascending distribution of the wasting leads to a striking appearance of the limbs. When the lower part of the calf is wasted the 'fat bottle' calf is produced, and wasting of the lower third of the thigh leads to the so-called 'inverted champagne bottle' limb. The muscles of the head and trunk almost invariably escape, though wasting of the spinati and pectoralis major has been described. Contractures occur, but are usually slight in proportion to the degree of wasting.

Changes in the electrical reactions of the muscles are present. The reaction to faradism is usually diminished or lost; that to galvanism is often less reduced, but the reaction of degeneration may be present. These electrical changes may be widespread and have been observed in muscles which were not the site of wasting.

The tendon reflexes are variable. They are usually diminished or

lost in the wasted muscles in proportion to the degree of wasting, but loss of the tendon reflexes may precede atrophy. The plantar reflexes are usually lost.

Sensibility may be unaffected, but there is often some impairment of appreciation of light touch, pain; and temperature over the periphery of the limbs. Deep sensibility is less often affected. Charcot and Marie, in their original paper, described vaso-motor changes in the extremities, and perforating ulcers may occur. The function of the sphincters remains normal.

The cranial nerves are usually normal, but optic atrophy has been described in a few cases and so, too, has inequality of the pupils, which is possibly due to implication of the ocular sympathetic fibres   Trigeminal neuralgia and anaesthesia rarely occur.

Symonds and Shaw have described an abortive form of the disease characterized by claw-foot and absence of the tendon reflexes in the lower limbs. This may occur in some members of a sibship, other members of which exhibit the disorder in its fully developed form. It has also been observed as the sole manifestation of the disorder in a family.

Diagnosis.

The onset of the muscular wasting in the lower limbs and its peculiar ascent from the periphery are distinctive features which usually render the diagnosis easy. In the muscular dystrophies affected muscles waste longitudinally and the distribution of the wasting is characteristic of the various forms. Dystrophia myotonica is distinguished by the presence of myotonia and by the distribution of the wasting, especially its selection of the sternomastoids and the quadriceps. Progressive muscular atrophy usually begins in adult life, and the feet are rarely the site of wasting. Friedreich's ataxia, like peroneal atrophy, is a hereditary disorder which gives rise to pes cavus, but nystagmus, ataxia, and extensor plantar responses are peculiar to the former, in which, moreover, muscular wasting is rare. Polyneuritis may cause wasting of the peripheral muscles of both upper and lower limbs, but it is rare in childhood and usually leads also to pain and tenderness of the muscles and more marked sensory impairment than occurs in peroneal atrophy

Prognosis.

The disorder runs a very slow course and arrest may occur at any stage   Since the wasting always remains confined to the limbs, the disease does not shorten life and many patients have been reported alive 45 or 50 years after the onset of symptoms. In spite of the deformities the degree of disability is often surprisingly slight.

Treatment.

No treatment will arrest the course of the disorder. Massage and appropriate exercises will help to maintain the nutrition of the muscles and to enable the patient to make the best use of his available resources. Appropriate surgical boots will be required.

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11. INFANTILE FORMS OF MUSCULAR ATROPHY

There has been considerable discussion as to the relationship between two muscular disorders of infancy, amyotonia congenita, or myatonia of Oppenheim (1900), and progressive spinal muscular atrophy of infancy, first described by Werdnig (1890) and Hoffmann (1891). Spiller (1913), on clinical grounds, threw doubt upon the distinction of these diseases, and recently Greenfield and Stern have pointed out that they are pathologically indistinguishable Nevertheless, since they differ in certain important clinical features, especially prognosis, it seems desirable to maintain the distinction.

Pathology.

Both these conditions are characterized by atrophy and chromatolytic degeneration of the ganglion cells of the anterior horns of the spinal cord and to a variable extent of the cranial nerve nuclei. The anterior roots are small and largely demyelinated. The peripheral nerves exhibit a high proportion of small finely myelinated fibres, and the muscles show simple atrophy with a number of very small fibres and a considerable amount of fat replacement in chronic cases. The diaphragm, however, is always normal.

Aetiology.

The cause of these conditions is unknown, but both may occur in more than one member of the same family, though a familial incidence is commoner in progressive muscular atrophy than in amyotonia congenita. Cases *have not been described in successive* generations. It is uncertain whether the diseases are due to the inheritance of an abnormal recessive gene or are acquired as a result of disturbance of foetal development. Although cases have been reported following acute infections it is doubtful if these play a part in aetiology.

The muscular disorder is secondary to degeneration of the motor ganglion cells of the spinal cord. This process has run its course at birth in amyotonia congenita, but continues to progress in Werdnig-Hoffman's disease.

AMYOTONIA CONGENITA

Definition: A congenital disorder characterized by extreme hypotonia and weakness of the muscles, without complete paralysis, with a tendency to improvement.

Symptoms.

The condition is usually present at birth, though frequently it is *not observed until the child is old enough to attempt to raise its* head. The most striking feature of the disorder is the extreme hypotonicity of all the muscles, which renders it possible for the limbs to be placed in most bizarre attitudes. The muscles, though weak, are not actually paralysed, but the child is unable to maintain any posture against the force of gravity. It is, therefore, at first unable to raise its head and, later, to sit or to stand, though it is able to move its legs if it is supported beneath the axillae. The tendon reflexes are absent and the reaction of the muscles to faradism is usually lost, while that to galvanism is retained. Muscular contractures tend to develop, especially in chronic cases, and severe scoliosis may occur. The intercostal muscles and diaphragm usually escape.

Diagnosis.

The diagnosis is usually easy, since no other condition characterized by extreme muscular hypotonia is present at birth and shows *the same tendency to improvement. Progressive spinal muscular* atrophy of infants usually develops during the second half of the first year of life, leads to conspicuous muscular atrophy, and terminates fatally. The muscular dystrophies all develop later in life and at the beginning exhibit localized muscular wasting.

Prognosis.

The general tendency of the disorder is to improve, and, if the patient survives intercurrent infections, a considerable degree of recovery may occur, though this is rarely complete.

Treatment.

Treatment must be directed to educating voluntary movement and to maintaining the nutrition of the muscles by massage and passive movements. Contractures may require tenotomy.

PROGRESSIVE SPINAL MUSCULAR ATROPHY OF INFANTS

Synonym: Werdnig-Hoffmann's paralysis.

Definition: A rare disorder, usually beginning at the age of 6 months and sometimes affecting several members of the same family, characterized by progressive muscular atrophy, and terminating fatally.

Symptoms.

Affected children are usually normal at birth and do not begin to exhibit the symptoms of the disorder until they are a few months old. Muscular weakness then begins in the muscles of the back and the pelvic and shoulder girdles, whence it spreads to the proximal, and later to the distal, muscles of the limbs. The affected muscles waste rapidly, though the wasting may be obscured by subcutaneous fat. Muscular fibrillation may be present. The intercostal muscles usually become affected and the bulbar muscles may suffer also, but the diaphragm usually escapes. The muscles exhibit the reaction of degeneration. The tendon reflexes are lost. Sensibility is usually unimpaired, though Collier and Adie have described analgesia over the limbs and trunk.

Diagnosis.

The condition must be distinguished from amyotonia congenita, which is present at birth and which is characterized by greater muscular hypotonia with less wasting, absence of complete paralysis and of involvement of the intercostals, and in which there is a tendency to improvement.

Prognosis.

The condition, as its name implies, is always progressive, and usually terminates fatally in a few months, though cases have been described in which survival up to 6 years has occurred.

Treatment.

No treatment of any value is known.

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12. FACIAL HEMIATROPHY

Definition: A trophic disorder of uncertain aetiology, characterized by progressive wasting of some or all of the tissues of one side of the face and sometimes extending beyond these limits.

Synonym: Parry-Romberg's syndrome.

Pathology.

Facial hemiatrophy, which was first described by Romberg in 1846, consists essentially of an atrophy which usually involves all the tissues of the face—the skin, the subcutaneous fat and connective tissue, the muscles, cartilage, and bone. The muscular atrophy is due to a disappearance not of the muscle-fibres but of the fat and connective tissue of the muscle. The tongue and soft palate often suffer in addition. The cartilage of the nose frequently becomes atrophic. That of the ear, larynx, and tarsus is less often affected. In two cases the changes characteristic of interstitial neuritis have been observed in the trigeminal nerve on the affected side.

The cerebral hemisphere on the affected side may be atrophic. Stief (1933) has described great vasodilatation of the ipsilateral hemisphere and round cell infiltration of the cervical sympathetic on the affected side.

Aetiology.

It is a disorder of early life, usually developing during the second decade, and is sometimes congenital. A number of cases, however, have been observed in which the onset has occurred in middle life or even old age. Among the predisposing causes local trauma to the head, face, or neck appears important. The disorder has sometimes been ascribed to local infections in the neighbourhood of the jaw and pharynx, for example alveolar abscess, and its onset has followed the extraction of teeth. General infections have been held responsible, but their importance is difficult to assess, except in the case of pulmonary tuberculosis, which has been described too frequently for its association with facial hemiatrophy to be a coincidence. Those who attribute the latter to a disorder of the cervical sympathetic believe that this may be involved in an apical pleurisy of tuberculous origin.

The immediate pathogenesis of facial hemiatrophy is unknown. Its association with scleroderma has been emphasized. Nevertheless, the two conditions appear to be distinct. Some workers have attributed it to a lesion of the trigeminal nerve. It is true that neuralgic pain is not uncommon in facial hemiatrophy, and facial anaesthesia has occasionally been observed. Lesions of the trigeminal nerve, however, are common, whereas facial hemiatrophy is rare, and it is unlikely that the former is the cause of the latter. Archamboult and Fromm have recently summarized the arguments in favour of attributing facial hemiatrophy to a disturbance of the sympathetic nervous system. The disorder has not uncommonly been observed in association with symptoms of paralysis of the cervical sympathetic, both of peripheral and of central origin, but either may occur without the other, and their relationship remains obscure.

Symptoms.

Wasting may begin at any point of the face and may either remain limited to one region, so that it has been described as corresponding to one division of the trigeminal nerve, or may spread, either slowly or quickly, to the whole face, sometimes extending to the side of the neck and even, as in a case of Martin's, involving the breast on the same side. Some authors would relate cases of progressive hemiatrophy of the whole body. When the disorder is well developed the patient's appearance is striking, the affected half of the face being sunken and wrinkled and presenting the appearance of old age, a marked contrast to the normal side. Very rarely both sides of the face are affected. The atrophy frequently involves the soft palate, tongue, and mucous membrane of the gums on the same side. Muscular weakness is absent. Falling of the hair of the face and scalp on the affected side is not uncommon. Pigmentary anomalies of the

skin, such as vitiligo, frequently occur, and facial naevus has been described. Pains of a neuralgic character are not uncommon and are frequently associated with tender spots. True tic douloureux may

Fig. 64. Facial hemiatrophy associated with atrophy of the ipsilateral cerebral hemisphere. (See also fig. 65).

occur. Sensory impairment is rare but cutaneous anaesthesia and analgesia have been encountered. Sweating and lacrimal secretion may be either diminished or increased on the affected side. Ocular sympathetic paralysis—myosis, ptosis, and enophthalmos—has been encountered in a proportion of cases and I have seen unilateral Argyll Robertson pupil. In other cases the pupil on the affected side has been larger than on the normal side.

Epileptiform convulsions, in some cases Jacksonian and in others generalized, have occurred in a small number of cases. I have seen one such case (Fig. 64) in which left facial hemiatrophy was associated with right-sided epilepsy, hemiplegia, hemianaesthesia, hemianopia, and aphasia, and atrophy of the left cerebral hemisphere was demonstrated by encephalography (Fig. 65). Migraine is com-

Fig. 65. Facial hemiatrophy with atrophy of the ipsilateral hemisphere resulting in dilatation of the ventricle on the same side and causing a local collection of air over the surface of the hemisphere in the region of the atrophy. Radiogram by Dr. Jupe. Same patient as fig 64.

mon. Facial hemiatrophy is sometimes associated with syringomyelia, and the presence of sclerodermia elsewhere in the body has often been observed.

Diagnosis.

The clinical picture is so striking that it can hardly be confused with anything else.

Prognosis.

The wasting may become arrested before the whole of the face is involved, but there is no means of determining whether or not this will occur. The disorder causes no disability.

Treatment.

No known treatment will arrest the progress of the disease. For cosmetic purposes Gersuny introduced melted paraffin into the subcutaneous tissues. X-ray irradiation is the most satisfactory method of relieving the neuralgic pains but the usual treatment of trigeminal neuralgia may be required.

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DISORDERS OF THE SPINAL CORD

1. ANATOMY OF THE SPINAL CORD

THE spinal cord lies within the vertebral canal, extending from the foramen magnum, where it is continuous with the medulla oblongata, *to the level of the first or second lumbar vertebra. It is oval in shape*, being flattened from before backwards, and exhibits two enlargements, in the cervical and lumbar regions, corresponding to the outflow of nerves to the limbs. At its lower end the spinal cord terminates *in the conus medullaris, from the end of which a delicate filament*, the filum terminale, is prolonged downwards as far as the posterior surface of the coccyx. The surface of the cord exhibits several longitudinal grooves, the deep anterior median fissure and the *shallower posterior median sulcus, while on the lateral aspect are* two sulci, the antero-lateral and the postero-lateral From the last two a series of root filaments emerge on each side of the cord. At intervals several filaments from the postero-lateral sulcus unite to form a dorsal or posterior root, upon which is situated a ganglion, the posterior root ganglion, and similarly those from the antero-lateral sulcus unite to form a ventral or anterior root. One anterior and the corresponding posterior root on one side join together just distally to the posterior root ganglion to form a spinal nerve. Thus from each side there arises a series of spinal nerves, and the spinal cord is regarded as divided into segments, one corresponding to each pair of spinal nerves. There are eight cervical, twelve dorsal, five lumbar, five sacral, and one coccygeal segments. The spinal cord, like the brain, is surrounded by three meninges. The pia mater is a fibrous membrane, which forms the immediate covering of the cord and from which fine septa penetrate into its substance. The arachnoid is a delicate, transparent membrane, which lies superficially to the pia mater, from which it is separated by the subarachnoid space which contains the cerebro-spinal fluid and which is bridged by numerous trabeculae. The arachnoid extends as low as the second sacral vertebra. Outside the arachnoid lies the dura mater, which forms a lining to the vertebral canal, from which it is separated by the epidural space containing fatty tissue and a thin-walled venous plexus. The dura mater extends a little lower than the arachnoid, to the second or third sacral vertebra. The spinal cord is suspended within its dural sheath by a series of ligamenta denticulata, which extend laterally from the sides of the cord to terminate in a tooth-like attachment to the inner aspect of the dura.

On transverse section the substance of the cord is seen to be divided into the central grey and peripheral white matter. The *grey matter is composed of ganglion cells and nerve-fibres and the* white matter of fibres only. The grey matter forms an H-shaped mass composed of an anterior and a posterior horn on each side, united by the grey commissure, in the centre of which is situated *the central canal. The anterior horns of grey matter contain the* ganglion cells, the axones of which compose the anterior roots and which constitute the lower motor neurones. These cells are not uniformly scattered throughout the anterior horns, but are arranged *in definite groups. In the cervical and lumbar enlargements it is* possible to distinguish an antero- and a postero-lateral, an antero- and a postero-mesial, and a central group. According to Bing: 'It may be said that the centres for the spinal musculature are to be *found in the dorso-mesial group, those for the muscles of the proximal* segments of the limbs in the ventro-mesial, while the two lateral groups govern the remaining segments of the extremities. The centres for the coarser movements of flexion and/extension are in the neighbourhood of the periphery, while *those for* the finer movements (e.g. of toes and fingers) lie nearer the central groups.'

The white matter, which consists of the longitudinal bundles of nerve-fibres, is regarded as divided into three columns. The anterior column lies between the anterior fissure and the anterior horn of grey matter with its emerging roots. The lateral column is situated on the lateral side of the grey matter, between the anterior and posterior roots, that is, between the antero-lateral and postero-lateral sulci. The posterior column lies between the posterior median septum and the posterior horn of grey matter and the posterior root. The paths of the fibres entering the spinal cord by the posterior roots are described elsewhere (see pp. 29 to 32). The anatomical situation of the various fibre-tracts of the spinal cord is best appreciated by reference to the diagram (Fig. 6, p. 30).

The Blood-supply of the Spinal Cord.

Arteries. The spinal cord is richly supplied with blood. There are two posterior spinal arteries, each derived from the corresponding vertebral or posterior inferior cerebellar artery and passing downwards upon the side of the medulla oblongata and throughout the whole length of the spinal cord, where it lies either in front of, or behind, the posterior nerve-roots. The single anterior spinal artery is formed by the union of a branch from each vertebral artery, and descends throughout the whole length of the spinal cord in the anterior median fissure. The spinal arteries are reinforced by segmental arteries, which enter each intervertebral foramen and are

derived from the vertebral, intercostal, and lumbar arteries. The spinal cord is thus surrounded by a vaso corona or arterial wreath, which unites the spinal arteries and which sends branches horizontally inwards to supply the white matter and the greater part of the posterior horns of grey matter. The anterior horns of grey matter are supplied by a special artery, the sulcocommissural, derived from the anterior spinal artery and distributed to the anterior horn on each side alternately.

Recent work (Bolton, 1939) suggests that the direction of blood flow is downwards in the anterior spinal artery and in the posterior spinal artery down to the lower cervical region, but that in the rest of the posterior spinal artery blood flow is derived from the terminal portion of the anterior spinal artery and is directed upwards as far as the upper thoracic region. Within the cord the anterior spinal artery supplies all but the posterior portion of the posterior column and posterior horn, which is supplied by the posterior spinal artery.

Veins. The spinal veins derived from the substance of the spinal cord terminate in a plexus in the pia mater, in which six longitudinal channels have been described. These pass upwards into the corresponding veins of the medulla oblongata and so drain into the intracranial venous sinuses. Segmental veins pass outwards along the nerve-roots to join the internal vertebral venous plexus, in which also blood flows upwards to the intracranial venous sinuses. Venous drainage through the intervertebral foramina is relatively unimportant.

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2. PARAPLEGIA

By paraplegia is meant paralysis confined to the lower limbs. This may be caused by a disorder of function at different levels. It may be psychogenic—in hysteria. It may occur as a result of a cerebral lesion, when it is so placed as to damage the pyramidal fibres from the leg areas of the motor cortex only. Cerebral paraplegia may thus be produced by a meningioma arising in the falx, *by thrombosis of the superior longitudinal sinus, by congenital cerebral lesions* (Little's disease), and in rare instances by thrombosis of an unpaired anterior cerebral artery. In such cases the lower limbs are usually spastic in extension. Paraplegia due to a lesion of the spinal cord is very much commoner and is the form usually encountered. Spinal paraplegia may be associated either with extension or with

flexion of the lower limbs, paraplegia-in-extension and paraplegia-in-flexion. Paraplegia may also be caused by a lesion of the cauda equina, or of the peripheral nerves to the lower limbs, as in polyneuritis. We are here concerned mainly with paraplegia due to lesions of the spinal cord.

Following a pyramidal lesion two mutually antagonistic reflex activities emerge, extensor hypertonia and the flexor withdrawal reflex (see p. 41). *The former is recognized as physiologically equivalent* to decerebrate rigidity in the animal, which, it will be remembered, is probably dependent upon the connexions of the vestibular nuclei with the spinal cord, i.e. the vestibulo-spinal tracts. The flexor withdrawal reflex, on the other hand, utilizes short spinal reflex arcs. After a lesion which involves the pyramidal tracts only, both sets of reflexes are potentially active, but extensor hypertonia predominates as a persistent tonic activity, *giving way only occasionally to* the flexor withdrawal reflex when a noxious stimulus excites the latter. If, however, a spinal lesion involves a sufficient extent of the cord to destroy not only the pyramidal fibres but also the vestibulo-spinal tracts, upon which extensor hypertonia depends, the flexor reflex, freed from its antagonist, manifests greatly heightened activity and dominates the picture. Violent flexor spasms occur in the lower limbs, which in severe cases finally become fixed in an attitude of flexion, with the heels approximated to the buttocks. Paraplegia-in-flexion may be the outcome of a progressive lesion of the cord, in which case it follows paraplegia-in-extension after an intermediate phase in which the balance swings between the two reflex systems. *After a traumatic lesion, causing immediate and complete severance of the cord, on the other hand, paraplegia-in-extension never occurs, because the vestibulo-spinal tract is interrupted from the beginning and, as soon as the stage of spinal shock has passed, paraplegia-in-flexion develops.*

Paraplegia-in-flexion.

In paraplegia-in-flexion three reflex activities are demonstrable: (1) the flexor withdrawal reflex, (2) excretory, and (3) sexual reflexes. We must also consider (4) the 'mass reflex' and (5) the tendon reflexes.

(1) *The flexor withdrawal reflex* has already been briefly described (see p. 41). *In paraplegia-in-flexion its activity is much enhanced.* Its receptive field is enlarged and it may be elicitable by a noxious stimulus applied to any part of the lower limbs and abdominal wall, or even with a high dorsal lesion as high as the nipple. The motor response is extremely vigorous, and strong flexion of the lower limb occurs at all joints, with upward movement of the great toe and

separation of the other toes. This is usually unilateral, but the opposite lower limb may also become flexed. The activity of the flexor reflex is depressed by spinal shock and by cutaneous or urinary infection. Both its receptive field and its motor response then shrink until it can be obtained only from the outer border of the sole, and yields only a contraction of the inner hamstring muscles.

(2) *Excretory Reflexes.* When reflex activity of the divided spinal cord is well established, in traumatic cases about three weeks after transection, reflex evacuation of the bladder and rectum and reflex sweating occur. The volume of fluid required to evoke reflex contraction of the bladder wall varies in different cases, but is usually about 6 or 8 oz. Reflex emptying of the bladder can be facilitated by deep breathing or by noxious stimuli applied to the skin of the lower limbs. Reflex evacuation of the rectum occurs in response to a volume of from 4 to 6 oz. Sweating occurs reflexly in response to cutaneous stimuli from the areas of skin supplied by the fibres of the sympathetic nervous system which leave the spinal cord below the level of the lesion.

(3) *Sexual Reflexes.* In paraplegia-in-flexion the cremasteric, dartos, and bulbo-cavernosus reflexes are present, and reflex erection of the penis and seminal emission can be evoked by handling the organ. Spontaneous priapism may occur. These sexual reflexes may be associated with contractions of the abdominal recti, the leg flexors, and the adductors of the thigh.

(4) *The Mass Reflex.* Reflex facilitation is probably responsible for the phenomenon named by Head and Riddoch 'the mass reflex', in which stimulation of the skin of the lower limbs and, when the lesion is high, of the lower abdominal wall evokes reflex flexion of the lower trunk muscles and the lower limbs, evacuation of the bladder and rectum, and sweating.

(5) *The Tendon Reflexes.* The tone of the extensor muscles is minimal in paraplegia-in-flexion, but the tendon reflexes can usually be elicited. Ankle clonus, however, never occurs.

Paraplegia-in-extension.

In paraplegia-in-extension tone predominates in the adductors of the hips and the extensors of the hips, knees, and ankles with a resulting posture of extension of the hip and knee and plantar flexion of the ankles. The knee- and ankle-jerks are exaggerated and patellar and ankle clonus are frequently present. The elicitation of the knee-jerk may evoke a sharp contraction of the adductors of the opposite hip, the crossed adductor-jerk. Reflex extension of the limb can often be obtained by applying a noxious stimulus, such as a scratch

from a pin, to the skin of the upper third of the thigh, and spontaneous extensor spasms may occur.

With this prevalence of extensor tone the flexor withdrawal reflex is relatively inhibited. Its field of elicitation is small compared with that found in paraplegia-in-flexion. After it has been evoked the limb regains its primary posture of extension by an active return of tone to the extensor muscles. Flexor withdrawal of one limb is usually associated with increased extension of the other, the crossed extensor reflex. The excretory reflexes which accompany paraplegia-in-flexion are absent, and the motor concomitant of erection of the penis is extension instead of flexion of the lower limbs.

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3. THE INNERVATION OF THE BLADDER

Anatomy and Physiology.

The sympathetic fibres from the bladder are derived chiefly from the first and second lumbar ganglia, with contributions from the third and fourth. These fibres ultimately unite to form the presacral nerve or superior hypogastric plexus, which lies in front of the bifurcation of the aorta. From this plexus are derived the two hypogastric nerves, each of which ends in a hypogastric ganglion on the lateral aspect of the rectum. The parasympathetic nerve-supply from the second and third sacral nerves also joins the hypogastric ganglia. The sympathetic is inhibitory to the detrusor muscle of the bladder and motor to the sphincter, while the parasympathetic produces the reverse effects.

In infancy the evacuation of the bladder occurs reflexly, the reflex arc running through the sacral region of the cord. The development

of control over bladder evacuation is associated with the growth of inhibition of the evacuation reflex, the path of the inhibitory impulses running in the sympathetic, which maintains closure of the sphincter and inhibition of the detrusor muscles. At the same time it becomes possible voluntarily to overcome this inhibition and so to initiate the act of micturition, which is then completed reflexly. Thus we can recognize three nervous mechanisms controlling bladder function—the sacral reflex arc for evacuation; the inhibitory influence of the sympathetic; and voluntary control overcoming the last-named and initiating micturition.

The paths in the central nervous system traversed by impulses concerned in sympathetic and voluntary bladder control are imperfectly known. The voluntary initiation of micturition usually occurs in response to an awareness of distension of the bladder. The part of the post-central convolution lying at the vertex of the cerebral hemisphere is the cortical centre for sensations derived from the bladder, and the corresponding area of the precentral convolution is probably the site of origin of motor impulses initiating the act of micturition.

Disturbances of Bladder Function.

(1) *Lesions involving the Sacral Reflex Arc.*

Since the sacral reflex arc is concerned in evacuation of the bladder its interruption usually causes retention of urine, which is produced by the unopposed action of the sympathetic. In tabes dorsalis the reflex is interrupted on its afferent side, owing to degeneration of the afferent neurones. Lesions of the conus medullaris of the spinal cord interrupt the central fibres of the reflex. Lesions of the cauda equina, if they destroy the second and third sacral roots, interrupt both the afferent and the efferent paths of the reflex and hence usually cause retention of urine. Even after severe lesions of the conus or cauda equina, however, 'reflex' evacuation of the bladder may develop, under the influence of a more peripheral autonomous nervous mechanism, probably the vesical plexus.

(2) *Lesions of the Spinal Cord above the Conus Medullaris.*

Incomplete lesions of the spinal cord may affect principally either the inhibitory fibres destined for the sympathetic outflow or the fibres concerned in the voluntary initiation of micturition. In the former case, the patient complains of difficulty in holding urine, and micturition is precipitate. This is a common symptom in the early stages of disseminated sclerosis. Moderately severe but still incomplete lesions of the spinal cord tend to impair voluntary control over micturition, so that retention of urine develops, owing to uninhibited action of the sympathetic. Retention of urine is thus

produced by spinal compression in its later stages, by transverse myelitis, and in the more advanced stages of disseminated sclerosis.

After complete interruption of conduction in the spinal cord, either by transection or by severe transverse lesions, above the conus there occurs an enhancement of reflex activity in the distal portion, and reflex evacuation of the bladder may then develop through the agency of the sacral reflex arc. It may be facilitated by stimuli applied to the sacral cutaneous areas.

(3) *Cerebral Lesions.*

The fibres concerned in the voluntary initiation of micturition may be interrupted at levels of the nervous system above the spinal cord, and retention of urine may then develop, usually in association with severe bilateral pyramidal lesions. Lesions involving the vertical region of the precentral cortex on both sides may in the same way cause retention of urine, as Foerster has shown, and impairment of function of this part of the cerebral cortex or of its descending paths is probably responsible for difficulty in micturition and retention of urine, which are not uncommon symptoms of intracranial tumour and of diffuse cerebral lesions.

Nocturnal enuresis in otherwise normal children probably arises in the first place as a result of delay in the development of inhibition of reflex bladder evacuation. Later, for psychological reasons, the child acquires abnormal conditioned reflexes whereby bladder evacuation continues to occur during sleep. Sometimes, however, enuresis in childhood is due to spina bifida occulta.

Treatment of Bladder Disturbances.

In the treatment of disturbances of the bladder function the underlying physiological principles must be borne in mind. When retention of urine occurs, adequate bladder drainage becomes necessary, and steps must be taken to combat the risk of infection of the urinary tract. (See p. 611 for the care of the bladder in paraplegia.)

In view of the fact that retention of urine is usually due to a relative preponderance of sympathetic influence, the action of the parasympathetic may be reinforced by drugs which stimulate its nerve-endings. Acetyl-choline may be administered in doses of 0·1 gm. intramuscularly or doryl in doses of 0·001 to 0·004 gm. by the mouth for this purpose.

Interruption of the sympathetic supply to the bladder by resection of the presacral nerve has been carried out in a small number of cases and good results are claimed for this operation. The same operation has been employed to interrupt pain impulses from the bladder in painful conditions such as inoperable carcinoma.

In cases of frequency of micturition or precipitate micturition due to predominant action of the parasympathetic, drugs which paralyse parasympathetic nerve-endings are indicated and belladonna is useful in such cases. At the same time ephedrine may be employed to stimulate the sympathetic. Belladonna owes what value it possesses in the treatment of nocturnal enuresis to its inhibitory effect upon the parasympathetic. Drug treatment alone, however, is rarely successful in this condition and requires to be combined with the education of reflex inhibition produced by suggestion, if necessary in the hypnotic state.

The Innervation of the Rectum

The nerve supply of the rectum is identical with that of the bladder (q.v.) and micturition and defaecation are physiologically comparable except that in the rectum voluntary control is exerted over the external sphincter only and the rectum lacks voluntary inhibition.

After destruction of the sacral innervation of the rectum automatic activity dependent upon a peripheral nervous plexus develops, the rectum contracting and the sphincter relaxing in response to a rise of tension within the rectum. This reflex activity is rendered more massive and complete when the sacral innervation is intact, e g. after complete transverse division of the spinal cord above the sacral enlargement. Owing to the small force of the rectal contraction, however, it is at best not very efficient and since the tone of the external sphincter is unaffected by transverse spinal lesions the tendency is for all disturbances of rectal innervation to cause constipation, though after complete transverse division of the spinal cord reflex defaecation may occur and may be facilitated by cutaneous stimuli applied to the sacral cutaneous areas.

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4. THE CARE OF THE PARAPLEGIC PATIENT

The general management of a patient suffering from paraplegia requires much care and is of as much importance as the correct *treatment of the cause of his disability*, for his disorder renders him extremely susceptible to complications which may prove fatal and, even when less serious, may considerably retard recovery.

Care of the Skin.

In paraplegia the skin is extremely liable to injuries which are slow in healing and readily become infected. A paraplegic patient should be nursed on a water-bed, which should be kept filled with warm water. Care should be taken that the bedclothes are warm and dry and free from rucks, and those in attendance upon the patient should be warned of the risks of a burn resulting if a hot-water bottle is placed in contact with the skin. Special care to avoid this will be necessary in the case of a patient who suffers from an impairment of sensibility. The patient should be bathed daily, the skin being thoroughly cleansed with soap and water and carefully dried. After this the back is well rubbed with methylated spirit or eau-de-Cologne and dusted with a dusting powder. To protect the bony prominences from pressure upon the bed the lower part of the back *and hips may be padded with gamgee tissue. A small cushion* should be placed under the Achilles tendons. The feet are separated by a firm bolster, and small cushions are placed under the knee-joints. The weight of the bedclothes is taken from the lower limbs by means of a cradle. The position of the patient should be altered from time to time, and care must be taken that when he is moved he is not dragged across the bed, but is lifted clear of the bed, turned, and *then replaced in the new position.*

Bed-sores are most likely to develop over the bony prominences, especially the heel, the tuber ischii, the sacrum, and the great trochanter. To obtain the best results in their treatment, the dressings should be frequently varied. The following are the most useful:

A. EMOLLIENTS.

   1. Ol. Ricini
      Tinct. Benzoini Co. āā
   2. Ungt. Zinci
      Tinct. Benzoini Co. āā
   3. Ol. Ricini
      Ungt. Zinci. āā
   4. Glycerini
      Tinct. Benzoini Co. āā

B. Stimulants.

 1. Eusol, 1 in 2,000.
 2. Liq. Aluminii Acetatis 2 per cent.
 3. Liq. Sodae Chlorinatae B.P.
 4. Fomentations.
 5. Liq. Argent. Nit. 1 or 2 per cent.
 6. Dry Gauze.
 7. Lotio Rubra = Zinci Sulph. gr. 1½.
      Tinct. Lavandulae Co. ₥. 10.
      Aq. ad ½ oz.

The black blister is a form of bed-sore which is common on the heel. The serous fluid which it contains should be aspirated with a syringe, but the skin covering it should be left intact. If deep sloughs or gangrenous areas fail to respond to dressings, they should be scraped out with a Volkmann curette, and gangrenous skin edges should be removed with scissors.

Care of the Bladder and Rectum.

When retention of urine occurs as a result of a lesion of the nervous system, cystitis almost invariably develops. Retention of urine must, therefore, be treated by some form of drainage of the bladder. In most cases this is best effected by catheterization A catheter must be passed thrice daily or it may be tied in and changed every two or three days, the latter being in many cases the most convenient method. The greatest care must be taken that the catheter and all the vessels and apparatus employed are sterile, and the operator must be scrupulous in his observation of an aseptic technique. Before passing the catheter the glans penis and urethra should be washed with a 1 in 4,000 solution of oxycyanide of mercury. As a precautionary measure, even in the absence of urinary infection, the patient should be given sodium acid phosphate in doses of 30 grains thrice daily, in order to maintain the urine acid. Hexamine is unnecessary.

If, in spite of these precautions, the bladder becomes infected, 20 grains of ammonium chloride or 45 grains of ammonium mandelate should be substituted for or combined with the sodium acid phosphate and given four times a day. The bladder will require to be irrigated at least once a day and in severe cases several times daily. A Higginson syringe may be used for this purpose, care being taken that not more than 6 oz. of fluid are introduced into the bladder at a time. The following solutions may be used for bladder lavage at a temperature of 105° F.:

A. WITH AN ALKALINE CYSTITIS.

1. Quinine sulphate, with as much acid as is necessary to dissolve it, 1 gr. to 1 oz.
2. Oxycyanide of mercury, 1 in 4,000.
3. Saturated boric acid mixed with equal quantity of boiling water, the resulting solution having a temperature of 105° F.
4. Acetic acid B.P.
5. Brilliant green, 1 in 2,000, followed by a wash-out with boric lotion.

B. WITH AN ACID CYSTITIS.

1. Normal saline.
2. Potassium permanganate, 1 in 2,000.
3. Silver nitrate, 1 in 2,000.
4. Eusol, 1 in 16,000 or 20,000.

In severe and intractable cases of cystitis, especially when compli-cated by pyelitis, continuous drainage of the bladder by supra-pubic cystotomy may be necessary, irrigation being then carried out through the suprapubic opening.

The constipation which is usually a troublesome complication of paraplegia should be treated by the administration of an aperient at night, two or three times a week, and by washing out the rectum the next day with an enema. In paraplegia the bowel empties itself very slowly after an enema and 'leaking' may occur for an hour or more, a point which is important to bear in mind in order to avoid the bed becoming wet and soiled. If the rectum and large bowel are allowed to become distended, sloughing of the mucous membrane is liable to occur, and in any case abdominal distension causes the patient serious discomfort. Such distension should be treated by the administration of a turpentine enema, after which a rectal tube should be left in position. A hypodermic injection of 1 c.c. of pituitrin is often useful for dispelling gas by increasing the tone of the intestinal muscle.

Sweating.

Severe lesions of the spinal cord are frequently followed by excessive sweating over the lower part of the body. A moist skin increases the risk of bed-sores. Since sweating is excited reflexly, the paralysed parts should be handled as seldom and as gently as possible, and the use of a cradle to keep the bedclothes from contact with the body also assists in diminishing the stimulation from which sweating results. Nocturnal sweating may be diminished by giving either liquor atropinae, ♏.2, in water, or ext. belladonnae sic. gr. j, as a pill, before the patient settles down for the night.

Muscular Spasms.

Involuntary spasmodic movements of the lower limbs are a troublesome and intractable symptom in many cases of paraplegia. Spasmodic extension may occur when extension is the predominant attitude of the lower limbs. Spasmodic flexion, which is encountered in paraplegia-in-flexion, is much commoner Flexor movements are reflexly excited by moving contact of the lower limbs with the bed-clothes, a slight movement of the limb being sufficient in many cases to excite a violent flexor spasm. As far as possible contact of the limbs with the bedclothes should be reduced. Light massage and a warm bath at bed-time frequently have a sedative effect, and the spasms may be diminished in frequency and severity by the use of sedative drugs, such as phenobarbital, gr. j. Hyoscine hydro-bromide, gr. 1/150th to 1/100th, administered hypodermically, is sometimes of value.

When there is no hope of recovery and the bladder is already paralysed flexor spasms may be relieved by the intrathecal injection of alcohol.

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5. INJURIES OF THE SPINAL CORD

Aetiology.

The spinal cord may be injured directly by penetrating wounds, for example, stabs or gun-shot wounds, in which case it may be penetrated by a missile or by fragments of bone. More frequently in civil life it suffers indirectly as a result of injuries of the vertebral column, either fractures, dislocations, or fracture-dislocations. The commonest sites of spinal injury in civil life are the lower cervical region and the thoracico-lumbar junction. The upper cervical region suffers next in frequency (Jefferson). Though the spinal column may be injured as the result of a blow leading to fracture at the site of the insult, more frequently it is injured by transmitted violence. Forcible extension of the neck may cause fracture of the odontoid process, but most spinal injuries are the result of forcible flexion A blow on the head which does not expend its violence in fracturing the skull may, by forcibly flexing the cervical spine, cause dislocation in the lower cervical region. Blows upon the shoulders, such as are caused by heavy objects falling from a height, cause forcible flexion of

the lower part of the spine, which usually yields at the thoracico-
lumbar junction. This type of injury is produced chiefly by in-
dustrial accidents. Fracture-dislocation may similarly result from
the patient's falling from a height on to the feet or buttocks. Lifting
a heavy weight, falls, and strains may cause displacement of an
intervertebral disk (see p. 634).

The spinal cord may be injured in the infant during birth as a
result of violent traction. Such injuries may arise in three ways.
Traction on the head may cause dislocation of the upper cervical
spine, which is usually immediately fatal. Traction separating the
head and shoulders, by exerting tension on the brachial plexus and
cervical spinal roots, may injure the spinal cord as well as producing
a brachial plexus palsy. In addition, violent traction, especially in a
breech presentation, may cause fracture-dislocation in the thoracic
or lumbar regions.

Spontaneous fracture-dislocation of the spine may occur when the
vertebrae are diseased, for example, in tuberculous caries or neo-
plasm of the vertebral column.

Pathology.

'*Concussion* of the spinal cord' is the term employed when the
cord is injured by transmitted violence without fracture or dislocation
of the vertebral column, e.g. by the passage of a bullet near the
spine without penetration of the dura. The axis cylinders are
broken up but the myelin sheaths remain intact. Spinal *contusion*
is defined as bruising of the cord without rupture of the pia mater,
resulting from compression. The contused cord is swollen and
exhibits small haemorrhages. Holmes has described the formation
of cylindrical cavities extending upwards or downwards for several
segments, usually situated in the *ventral* part of the dorsal
columns or in the dorsal horn of grey matter, and filled with
brownish, gelatinous material. Microscopically, besides oedema
and haemorrhages the contused cord exhibits swelling of the axis
cylinders and disintegration of their myelin sheaths. In severe
cases both completely disappear and the cord may be markedly
softened. Ascending and descending degeneration of the long tracts
follows the focal lesion. *Laceration* of the cord implies an injury of
greater severity than contusion, leading to rupture of the pia mater
and in the most severe cases the cord is completely transected.
When a wound penetrates the dura mater, meningitis is liable to
occur as a complication of spinal injury. Rupture of the pia in such
cases increases the risk of myelitis developing. Injuries of the
vertebral column damage the spinal roots as they pass through the
intervertebral foramina.

Symptoms.

The symptoms of spinal injury depend upon the severity and situation of the lesion. Injury to the cord does not necessarily follow damage to the vertebral column, for example, dislocation of the cervical spine without injury to the cord is not rare. An injury to the cord in the upper cervical region is usually rapidly, if not immediately, fatal, since it causes paralysis both of the diaphragm and of the intercostal muscles

Complete interruption of the spinal cord leads immediately to flaccid paralysis with loss of all sensation and most reflex activity below the site of the lesion, and paralysis of the bladder and rectum. Muscular paralysis and sensory loss are irrecoverable, but, as after from one to four weeks the stage of spinal shock passes off, reflex activity develops in the divided portion of the cord and the patient presents the picture of paraplegia-in-flexion, see p. 604. For the motor symptoms of spinal interruption at different levels, see p. 631

Lesions of the cord less severe than complete interruption such as spinal contusion may lead to an equally severe immediate disturbance of function, or symptoms may increase in severity for several days *pari passu* with the development of oedema in the cord Slight spinal injuries cause motor symptoms of incomplete division (see p. 604) without complete sensory loss, or, if the injury is limited to one-half of the cord, a partial or complete Brown-Séquard syndrome (see p 32). Spinal concussion may cause temporary complete paraplegia with sensory loss mainly of the posterior column type.

A spinal injury which causes little or no damage to the cord at the time of its occurrence may lead to the development of spinal symptoms after a lapse of years. Gradual spinal compression may occur as a result of localized vertebral collapse (Kümmel's disease) or of osteoarthritic changes, though in both cases spinal roots are compressed more often than the cord itself. Gradual interference with spinal function may also result from localized adhesive arachnoiditis, which is sometimes a late sequel of spinal injury, or even in the *absence of this probably as a result of slow degeneration* of the arteries of the cord.

Injuries of the Cauda Equina. Fracture-dislocation of the spine below the first lumbar vertebra damages only the roots of the cauda equina. In civil life unilateral injuries of the cauda are rare, though the severity and extent of the injury may differ on the two sides. Paralysis of the bladder, rectum, and sexual functions immediately follows the injury. The motor, sensory, and reflex disturbances are similar to those more gradually produced by slow compression of the cauda equina and are described on p. 633.

Diagnosis.

The diagnosis is usually obvious, the only question being the nature of the injury to the cord. If Queckenstedt's test yields no evidence of spinal block it may be assumed that the cord is not being compressed. Haematomyelia may follow a slight injury but is characterized by damage to the central grey matter predominantly, leading to atrophic paralysis, analgesia, and thermo-anaesthesia at the level of the lesion.

Prognosis.

The prognosis of a severe injury of the spinal cord is always grave. If the respiratory muscles are not immediately paralysed and if the patient survives the stage of shock, death may occur from urinary or cutaneous infection, or, in the case of penetrating wounds, from meningitis or myelitis. Nevertheless, experience of the results of war injury of the spinal cord showed that it is possible for a patient with a completely divided cord to retain good general health indefinitely under careful supervision. When the cord has been incompletely divided, the prognosis is better, but, in the absence of infections of the bladder and skin, the limit of functional improvement will be reached when the shock has passed off, usually in from one to two months after the injury. After spinal concussion recovery is usually good though some abnormal physical signs may remain. The prognosis of cauda equina injuries is better than that of injuries of the cord itself, since the roots of the cauda are capable of regeneration.

Treatment.

The scope of surgery in the treatment of injuries of the spinal cord has been much discussed and the modern tendency in this respect is conservative. It has to be recognized that in most cases the maximal injury has been produced at the time of the accident and the condition of the cord is both non-progressive and irreparable. Moreover, for several weeks after the injury spinal shock may render it impossible to decide whether interruption of the cord is complete. When there is reason to believe that the cord has been completely divided, surgery cannot accomplish anything, and open operation is contraindicated by the presence of local sepsis, visceral complications, and secondary infective conditions. On the other hand, when there is radiographic evidence of gross bony deformity or of the presence of a foreign body in the spinal canal and clinical examination indicates that the cord has not been completely divided, and when in such cases recovery of function has begun but has become arrested, surgical intervention offers the hope of relieving compression or

cicatricial contraction, which may be retarding recovery. In such cases an exploratory laminectomy is indicated, and this may also be required to deal with severe persistent root pains, due to compression of posterior nerve-roots. The scope of manipulative reduction of vertebral deformity in cases of spinal injury is not as yet defined, but this procedure may sometimes be indicated as an early treatment of cases of incomplete division following vertebral injury when the surgeon can feel sure that it entails no risk of increasing the severity of the damage. In cases of injury of the cauda equina the most that can be hoped from operation is the relief of pressure which may be retarding regeneration of the roots. The general management of cases of injury of the spinal cord and cauda equina is described in the section, 'The care of the paraplegic patient' (see p. 610).

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6. HAEMATOMYELIA

Definition: The term 'haematomyelia' implies the occurrence of bleeding within the substance of the spinal cord. Haemorrhages occur within the cord in a variety of pathological states. Petechial haemorrhages are found in acute inflammatory conditions, such as acute anterior poliomyelitis, in toxic states, in blood diseases, especially those accompanied by purpura, in asphyxia, and as a sequel of severe convulsions. Haemorrhages also occur as a result of injury, in spinal concussion and contusion, as well as laceration of the cord

following fracture-dislocation of the spine and the penetration of the spinal canal by bullets. The term 'haematomyelia', however, is usually reserved for extravasation of blood within the spinal cord occurring in the absence of any of the conditions already mentioned.

Aetiology.

Haematomyelia in the sense just defined may develop in the absence of any discoverable exciting factor. Not uncommonly, however, it follows an event which may be supposed to have exposed the spinal cord to transmitted violence, though this often seems slight in proportion to the severity of the resulting symptoms. Forcible extension of the cervical spine following a blow on the head may precipitate haematomyelia and it may follow diving, again probably as a result of sudden extension of the neck. Blows on the spine and falls are sometimes held responsible. There is evidence that possibly a congenital abnormality, for example an intramedullary angioma, may sometimes be a predisposing factor, and spontaneous haemorrhage into a syringomyelic cavity may occur. Haematomyelia usually occurs in early adult life, and males are more frequently affected than females.

Pathology.

The cervical enlargement is the commonest site of haemorrhage, and haemorrhages elsewhere are rare. The bleeding occurs primarily in the central grey matter and tends to spread upwards and downwards, assuming a round or oval form, according to its longitudinal extent. It may extend into the white matter, but usually this suffers from compression rather than from direct invasion by the haemorrhage. At first red, the haemorrhage in the later stages becomes brown and may finally be represented by a cystic cavity containing yellow fluid. Surrounding regions of the cord exhibit an infiltration with compound granular cells and glial reaction. There is destruction and disappearance of the ganglion cells of both anterior and posterior horns of grey matter at the site of the haemorrhage and some degree of ascending and descending degeneration is usually found in the tracts of the white matter.

Symptoms.

The onset of symptoms is usually rapidly progressive, though after an injury there may be a sudden impairment of function of the spinal cord, followed later by a progressive increase in symptoms. Sometimes the onset is more gradual and the symptoms may increase in severity over a period of several days. Since the cervical enlarge-

ment is the commonest site of haemorrhage, symptoms of a lesion
in this situation will alone be described in detail. In some cases the
patient complains at the onset of severe pain in the neck radiating
down one or both upper limbs. In other cases pain is absent, but there
may be paraesthesiae, such as numbness and tingling. Muscular weak-
ness rapidly develops It is usually most marked in the upper limbs,
one of which may suffer more than the other. In the upper limbs the
paralysis is due to destruction of the anterior horn cells and hence
is associated with muscular atrophy and diminution or loss of the
tendon reflexes. It may be limited to the muscles innervated by the
upper segments, cervical 5 and 6, or by the lower segments, cervical
8 and dorsal 1, of the cervical enlargement. Below the level of the
haemorrhage the motor symptoms are those of spastic paralysis
which may be slight or severe in the lower limbs and may affect the
two sides unequally.

The most prominent sensory changes are due to destruction of the
sensory fibres in the grey matter of the cord at the level of the
haemorrhage. When this extends into the posterior horns and
destroys the ganglion cells, all forms of sensibility will be impaired or
lost over the whole or part of the upper limbs. When the destruction
is limited to the region of the posterior grey commissure there is
no disturbance of appreciation of light touch, posture, or passive
movement, but analgesia and thermo-anaesthesia occur over several
segmental cutaneous areas below the upper level of the haemorrhage,
which interrupts the fibres subserving these forms of sensibility at
their decussation. It is not uncommon to find some impairment of
appreciation of pain, heat, and cold, over the trunk or lower limbs on
one or both sides, owing to compression of the spino-thalamic tract.
Postural sensibility may be impaired in the lower limbs, but not
as a rule to a severe extent, owing to compression of the posterior
columns.

The tendon reflexes effected by muscles which are the site of
atrophic paralysis are diminished or lost. Those of the lower limbs
may be exaggerated, but I have known them also lost in cervical
haematomyelia, probably as a result of damage to the vestibulo-
spinal tracts. The abdominal reflexes are diminished or lost and the
plantar reflexes are extensor when the pyramidal tracts are damaged.
Sphincter disturbances are usually proportional to the severity of
the paraplegia.

Dorsal and lumbar haematomyelia are characterized by the
rapid development of more or less complete paraplegia and sensory
loss below the level of the lesion. Retention of urine is common.

The cerebro-spinal fluid may be normal or may show an increase in
its protein content, with or without xanthochromia.

Diagnosis.

Apart from traumatic lesions, there is no condition in which a lesion of the spinal cord develops so rapidly as in haematomyelia. The onset of transverse myelitis is subacute rather than acute, and it is often preceded for days or even for weeks by pains in the spine. It is often associated with inflammatory changes in the cerebro-spinal fluid and when, as in most cases, it is syphilitic in origin, the Wassermann reaction in the fluid and probably also in the blood will be positive. Acute anterior poliomyelitis can be differentiated from haematomyelia by its more gradual, febrile onset, by the wide distribution of the atrophic paralysis, by the absence of sensory loss and of pyramidal lesions, and by the occurrence of a pleocytosis in the cerebro-spinal fluid. Haemorrhage into a syringomyelic cavity constitutes a form of haematomyelia which it is important to recognize. The pre-existence of syringomyelia may be suggested by a history of cyanosis, painless injuries or trophic lesions of the fingers, and by the presence of bulbar symptoms and of associated abnormalities, such as scoliosis.

Prognosis.

The mortality rate is low, and most sufferers from haematomyelia survive. Death may occur from upward extension of the haemorrhage leading to paralysis of the diaphragm, through involvement of the spinal origin of the phrenic nerves, or from infection of the urinary tract or other complications of paraplegia. In patients who survive, considerable improvement may be expected. Atrophic paralysis and sensory loss due to destruction of the grey matter are permanent, but even these diminish in extent, as recovery occurs in ganglion cells and fibres which have been compressed but not completely destroyed. A steady improvement may be expected in the power of the lower limbs and in many cases this may return to normal, though exaggeration of the tendon reflexes and extensor plantar responses may persist. When haemorrhage has occurred into a syringomyelic cavity, much less improvement in the immediate symptoms can be expected and the prognosis is that of syringomyelia.

Treatment.

Complete rest is essential as long as the haemorrhage continues. It is doubtful if any special posture is of value. An icebag may be applied over the region of the spinal cord affected. Morphine should be given, as it is probably the most valuable drug in the treatment of haemorrhage. Vaso-constrictor drugs should be avoided, since they tend to raise the blood-pressure, but the various preparations which are designed to increase the coagulability of the blood

may be of value. Potassium iodide in doses of 5 to 10 grains may promote the absorption of the haemorrhage and may be combined with magnesium sulphate in ½-drachm doses for the relief of oedema of the cord. When paraplegia is present this will require appropriate treatment. Two weeks after the onset massage and passive movements of the upper limbs may safely be begun.

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7. COMPRESSION OF THE SPINAL CORD

Aetiology and Pathology.

Compression of the spinal cord may be due to:

Disease of the Vertebral Column. The commonest of such diseases leading to spinal compression are tuberculous osteitis (Pott's disease) and secondary carcinoma. Less frequent causes include primary *neoplasms arising from vertebrae, such as sarcoma, myeloma, osteoma,* and chondroma of an intervertebral disk, and other forms of osteitis, such as syphilitic osteitis and osteitis deformans of Paget The cord may occasionally be compressed by prolapse of an intervertebral disk at any level or as a result of erosion of vertebrae from without by sarcoma, or by aneurysm of the aorta. Compression due to vertebral injury is described on p. 613.

Intravertebral causes of compression include extradural abscess, pachymeningitis due to syphilis, tuberculosis, or exceptionally to pyogenic organisms, infiltration of the meninges with Hodgkin's lymphogranuloma and leukaemic or chloromatous deposits, meningitis circumscripta serosa, parasitic cysts, such as the echinococcus and cysticercus, and extramedullary and intramedullary spinal tumours.

(1) *Vertebral Disease.*

(i) *Tuberculous spinal osteitis* usually occurs in children and young adults but no age is exempt. The infective process generally begins

in the body of the vertebra, and spreading to adjacent bodies leads
to their collapse and so produces an angular deformity of the spine.
It is rare for the deformity as such to be an important factor in
compression of the spinal cord, which is more frequently due either
to an extradural tuberculous abscess or to tuberculous pachymenin-
gitis. In addition to actual compression of the cord, which may,
however, be absent, interference with the vascular supply of subjacent
segments, either by compression of radicular arteries or endarteritis,
is an important factor in the production of paraplegia. Paraplegia
occurs in about 11 per cent. of patients with Pott's disease, usually
within two or three years of the onset, but in some cases after many
years of apparent quiescence. The dorsal cord is commonly affected.
Syphilitic spinal osteitis is a rare cause of spinal compression and
produces effects similar to those of tuberculous caries. In Paget's
osteitis deformans softening and collapse of vertebrae occur without
abscess formation.

(ii) *Neoplasms of the Vertebral Column.* Secondary carcinoma is the
commonest vertebral neoplasm. It is rare before the age of 35. The
primary growth is most frequently situated within the breast, thyroid,
prostate, or lung, less frequently in the uterus, stomach, kidney, or
elsewhere. Although the vertebral metastasis may be blood-borne,
the spine is not uncommonly involved at the same segmental level
as the primary growth, which in such cases probably reaches it via
the perineural lymphatics. The carcinomatous deposits erode the
spongy portions of the vertebral bodies, which finally collapse. The
spinal cord may be compressed as a result of the spinal deformity or
by an intravertebral extension of the growth. Usually the spinal
roots are compressed earlier and more severely than the cord itself.

Sarcoma may arise from a vertebra or invade the spinal column
from a neighbouring tissue. Myeloma usually arises simultaneously
in numerous vertebral bodies and frequently also in other bones,
especially the ribs. Erosion of vertebral bodies leads to collapse.
Bence-Jones proteose is found in the urine. Osteomas and chondro-
mas are rare tumours which usually arise from the posterior part
of a vertebral body or an intervertebral disk and hence compress
the cord anteriorly. Deposits of Hodgkin's lymphogranuloma and
leukaemic metastases usually infiltrate the dura mater extensively
on its outer surface but may occasionally invade the cord itself.

(2) *Spinal Tumour.*

Spinal tumours are conveniently divided into extradural and
intradural growths, the latter being further subdivided into those
arising outside the spinal cord—extramedullary tumours, and within
the cord—intramedullary tumours. Excluding secondary carcinoma

of the vertebrae Elsberg (1925) found that 10 per cent. of spinal tumours were extradural, 67 per cent. were extramedullary, and 14 per cent. were intramedullary.

The origin and nature of extradural tumours have been described in the previous section. The histology of intradural spinal tumours is less advanced than the study of tumours of the brain, and there is therefore little agreement as to their classification. The commonest extramedullary tumours are endotheliomas and neurofibromas. According to Antoni the latter are twice as common as the former, while in Elsberg's series the former were two and a half times as frequent as the latter. Neurofibromas usually arise from spinal roots, the posterior more frequently than the anterior. They may be single or multiple and may or may not be associated with generalized neurofibromatosis. Endotheliomas may arise either from spinal roots or from the meninges. Sarcoma may be either localized or diffuse. Psammoma is probably a calcified endothelioma. Lipomas occasionally occur. Chordomas are rare, malignant tumours arising from a remnant of the notochord. Spinal chordomas are almost invariably situated in the sacro-coccygeal region. As Cairns and Russel have recently shown, metastatic deposits from all forms of cerebral glioma may infiltrate the spinal meninges. Exceptionally an extramedullary tumour may grow out through an intervertebral foramen, thus adopting a dumb-bell shape. The extraspinal portion may be palpable.

Kernohan and others, who have recently investigated the histology of intramedullary spinal tumours, claim to have recognized varieties corresponding to most of the cerebral gliomas. Forty-two per cent. of intramedullary tumours, according to these authors, are ependymomas, and the remainder includes spongioblastomas, astroblastomas, medulloblastomas, oligodendrogliomas, ganglioneuromas, and haemangioblastomas.   Angiomatous malformations occasionally occur and may have a considerable longitudinal extent   Leukaemic deposits may occur within the cord and gumma and tuberculoma are occasionally found. Spinal tumour may arise as a complication of syringomyelia. Cavitation, however, may occur within a spinal tumour or in the adjacent region of the cord.

Both sexes are equally liable to spinal tumour, which may develop at any age, but in over 80 per cent. of cases symptoms first appear between the ages of 20 and 60. The thoracic region of the cord is the commonest site of extradural and extramedullary tumours, the lower cervical of intramedullary tumours. Approximately two thirds of extramedullary tumours are situated on the dorsal or dorso-lateral aspects of the cord and approximately one-third on the ventral or ventro-lateral aspects (Elsberg).

(3) *Meningeal Inflammation.*

Spinal compression may be due to pachymeningitis. This rare condition is sometimes syphilitic but may be metastatic from a pyogenic infection leading to epidural abscess. Tuberculous pachymeningitis occurs as a result of extension of infection from tuberculous osteitis. The condition known as meningitis circumscripta serosa or adhesive spinal arachnoiditis is not completely understood. Adhesions are found between the leptomeninges and may be circumscribed or extensive. Occasionally they enclose encysted collections of cerebro-spinal fluid. Infection, including syphilis, and spinal trauma may play a part in aetiology. Although adhesive arachnoiditis interferes with the functions of the cord, spinal compression probably plays little part in its ill effects. Stookey considers that the cord suffers from being anchored by the adhesions, as a result of which its normal movements on respiration produce repeated small traumas. The blood supply of the cord also is impaired.

(4) *Parasytic Cysts.*

Echinococcus cysts are not uncommon causes of spinal compression in some countries. They are usually extradural. Cysticercus cysts are also occasionally encountered.

Effects of Compression upon the Cord.

Spinal compression, however produced, affects the cord in several ways. Direct pressure interferes with conduction in the spinal roots and in the cord itself. Pressure upon the ascending longitudinal spinal veins leads to oedema of the cord below the site of compression. Compression of the longitudinal and radicular spinal arteries leads to ischaemia of the segments of the cord which they supply. These vascular disturbances cause local oedema of the cord with degeneration of the ganglion cells and of the white matter. Areas of softening may develop—so called compression myelitis. Finally, obstruction of the subarachnoid space causes loculation of the cerebro-spinal fluid below the point of compression and leads to characteristic changes in its composition.

Symptoms.

The symptoms of compression of the spinal cord differ to some extent according to whether the source of compression is extradural, extramedullary, or intramedullary and according to its segmental level. The frequency, however, with which it is impossible to determine the relationship of the site of compression to the cord before operation indicates the similarity of the symptoms produced by pressure arising in different situations. It will be convenient,

therefore, first to describe the general symptoms of spinal compression and then to discuss how they may differ according to the site and segmental level of the lesion.

Mode of Onset.

The onset of symptoms is usually gradual, especially when they are due to a spinal tumour, but is more rapid in carcinoma of the vertebral column. In Pott's disease it is usually gradual but paraplegia may develop acutely. Approximately two-thirds of sufferers from spinal tumour come to operation between the first and second years after the onset of symptoms. Sometimes the interval is considerably longer. The first symptoms are usually sensory, the commonest being pain radiating in the distribution of one or more spinal roots. Root pains are usually severe in vertebral collapse from all causes and in pachymeningitis. In the case of spinal tumours they are most frequently encountered when the tumour is extramedullary and least in intramedullary tumours. The pains may be unilateral or bilateral and are frequently described as burning or constricting and may be associated with soreness of the skin and tenderness of the deeper structures. They are often intensified by movements of the spine and by coughing and sneezing, and they may be temporarily relieved by changes in posture. Pain in the back is not uncommon and is especially frequent in the case of tumours of the cauda equina and in malignant disease of the vertebral column. Compression of the spino-thalamic tracts may cause pain of a peculiarly unpleasant character referred to distant parts. Thus pain in a lower limb may be a symptom of compression of the cervical cord. Paraesthesiae may also be produced by compression of the ascending sensory tracts and take the form of numbness, coldness, or a sense of weight in the limbs.

Motor symptoms usually develop later than sensory. Weakness, stiffness, and unsteadiness of a limb may occur. When the cervical cord is compressed the order in which the limbs are affected is usually, as Elsberg points out, first one upper limb, then the lower limb on the same side, next the opposite lower limb, and finally the opposite upper limb. When the compression is situated below the cervical enlargement motor symptoms are confined to the lower limbs, one usually becoming weak before the other. Exceptionally, paraplegia rapidly develops. Sphincter disturbances are usually late in appearing, even in the case of tumours of the conus medullaris and cauda equina.

Motor Symptoms.

Compression of anterior roots or of the anterior horns of grey matter leads to a progressive lower motor neurone lesion,

characterized by weakness, wasting, and fibrillation of the muscles innervated by the affected segments. These symptoms are most conspicuous when the cervical or lumbo-sacral regions are compressed. Wasting of the intercostal muscles is similarly produced by a lesion of the thoracic cord.

Compression of the pyramidal tracts causes spastic weakness of the muscles below the level of the lesion. One side of the body is frequently involved before the other, but later spastic paraplegia-in-extension develops and as interruption of conduction in the cord becomes complete this gives place to paraplegia-in-flexion.

Objective Sensory Changes.

Compression of posterior spinal roots at the level of the lesion causes hyperaesthesia and hyperalgesia of the corresponding cutaneous areas. Anaesthesia and analgesia may follow, though owing to overlapping of the cutaneous supply of adjacent roots, this will not be detected unless more than one root is involved. Compression of the long ascending sensory tracts leads to impairment of sensibility in distant parts of the body. Several forms of dissociated sensory loss are encountered. Compression of the spino-thalamic tract causes impairment of appreciation of pain, heat, and cold on the opposite side of the body, but owing to a lamination of the fibres of the tract certain cutaneous areas may escape. Thus it is common to find sensibility unimpaired over the areas supplied by the sacral segments of the cord. Less frequently the sacral segments are affected early, but an area of normal cutaneous sensibility intervenes between them and an area of sensory loss at a higher level. The upper limit of the area of analgesia and thermo-anaesthesia is frequently several segments below the level of the lesion. This discrepancy occurs when the uppermost sensory fibres compressed in the cord are those which have decussated several segments below. It is exceptional to find that appreciation of pain, heat, and cold is affected to an equal extent. Not uncommonly cold is still felt over an area which is anaesthetic to heat, and sometimes a cold object, though not recognized as cold, evokes an unpleasant painful sensation. Cutaneous anaesthesia to light touch is frequently absent until the late stages, probably on account of the bilateral path of fibres subserving this form of sensibility. Appreciation of posture, passive movement, and of vibration is impaired to a variable extent and frequently more upon one side than upon the other. Although these forms of sensibility, which depend upon the integrity of the posterior columns, are likely to be affected early when the source of compression is posteriorly situated, they frequently also suffer when the cord is compressed from in front.

Tenderness of the spine on pressure or percussion may arise in two ways. When vertebrae are diseased or subjected to erosion by a tumour, their spinous processes are likely to be tender. When the vertebrae are normal, however, compression of the spinal cord or posterior roots may lead to tenderness of the spines of the vertebrae innervated by the segments affected. In the latter case the tender vertebra is not necessarily the one overlying the lesion, but is often situated at a lower level, since the segments of the spinal cord do not correspond with the vertebrae in which they are situated (see below). When the cervical cord is compressed, flexing or extending the cervical spine frequently causes pain, numbness, or tingling, radiating into the regions innervated by the affected part of the cord. This symptom may occur both with extramedullary and intramedullary tumours.

The Reflexes.

Compression of the spinal cord at a given segmental level leads to diminution or loss of reflexes when the central portion of the reflex arc passes through the segment affected. When the pyramidal tract is simultaneously compressed, reflexes below the level of the lesion show the changes associated with pyramidal disease, that is, the tendon reflexes are exaggerated, the cremasteric and abdominal reflexes are diminished or lost, and the plantar reflexes are extensor. The reflexes are, therefore, often of value in the localization of a spinal lesion, especially when a reflex mediated by one spinal segment is diminished and one transmitted by a slightly lower segment is exaggerated. For example, a lesion extending down to the fifth cervical segment but not involving the sixth cervical is likely to lead to diminution or loss of the biceps and supinator jerks, which depend upon the integrity of the former segment, while the triceps jerk, of which the reflex arc passes through the sixth cervical segment, may be exaggerated. The segmental levels of the various spinal reflexes are given on pp. 39–42.

The Sphincters.

The sphincters are not as a rule affected in the earliest stages of spinal compression, but later precipitancy or difficulty of micturition usually develops and later still retention of urine is common, or the bladder may be emptied automatically. Constipation usually occurs, but when there is severe paraplegia there may be incontinence of faeces. Sphincter changes may occur at an earlier stage in the case of tumours involving the cauda equina and conus medullaris than when the compression is situated at a higher level.

Autonomic Symptoms.

Autonomic symptoms may be of value in the localization of a spinal lesion. When there is considerable interruption of conduction in the spinal cord the control of higher centres over autonomic functions below the level of the lesion is impaired. In such cases excessive sweating frequently occurs over the parts of the body thus isolated from higher control. It is important to note that since the sympathetic outflow from the spinal cord is limited to the region between the first dorsal and the second lumbar segments, the upper level of the cutaneous distribution of autonomic disturbances does not as a rule correspond to that of the sensory symptoms of a lesion at a given level of the spinal cord; see p. 814. Fay (1928) has emphasized the value of vasomotor and pilomotor reactions in the determination of the upper level of a lesion of the cord. Oedema of the lower limbs is not uncommon in cases of severe spinal compression, as in paraplegia from other causes.

The Cerebro-spinal Fluid.

Examination of the cerebro-spinal fluid is of great diagnostic importance, since obstruction of the spinal subarachnoid space produces characteristic changes in its chemical composition and in its pressure below the block.

Chemical Changes. The essential chemical abnormality is a rise in the protein content of the fluid, which usually lies between 0·1 and 0·5 per cent. In addition the fluid is yellow in colour—xanthochromia—in about 40 per cent. of cases and may coagulate spontaneously. An excess of mononuclear cells in the fluid may be present when the source of compression is inflammatory, and exceptionally in cases of tumour. A rise in the protein content of the fluid is most marked in cases of extramedullary spinal compression, and may be slight when the source of pressure is extradural or intramedullary. It is important to note that the protein may be normal or only slightly raised when the cord is compressed in the cervical region, whatever the cause of compression. A rise of the protein content has been observed in the fluid removed *above* a tumour of the cauda equina.

Manometry. Manometry is carried out by the method described on p. 117. The pressure of the fluid is not infrequently subnormal below an obstruction of the spinal subarachnoid space, and variations in pressure corresponding to the pulse and respiration are often diminished or absent.

Queckenstedt's test affords a valuable evidence of spinal subarachnoid block and should be carried out, as described on p. 118, in every case in which this is suspected. If obstruction of the spinal sub-

arachnoid space completely cuts off the lumbar sac from the cerebral subarachnoid space, jugular compression produces no alteration in the pressure of the fluid below the obstruction. If the obstruction be incomplete, both the rise and the fall of the pressure may be slower than normal. It must be remembered that holding the breath, coughing, sneezing, grunting, and abdominal compression may raise the pressure of the cerebro-spinal fluid, even below an obstruction. If no rise of pressure in the spinal manometer follows jugular compression, this may be accepted as almost conclusive evidence of obstruction of the spinal subarachnoid space. A normal Queckenstedt's test, however, cannot with equal certainty be accepted as indicating that spinal block is absent. According to Elsberg, a normal rise of pressure occurs in 20 per cent. of cases of spinal block.

Lumbar Puncture at Different Levels. The presence of a tumour of the cauda equina may lead to a failure to obtain cerebro-spinal fluid by lumbar puncture at the site of election below the fourth lumbar vertebra, if it completely fills the spinal canal at this point. If this occurs in a patient who is suspected of having a tumour of the cauda equina, the lumbar puncture needle should be inserted in the space above, and if this also results in a dry tap, in successively higher spaces, if necessary up to that between the twelfth dorsal and first lumbar vertebrae, in the hope that it may thus be possible to reach the subarachnoid space above the upper level of the tumour.

Exacerbation of Symptoms following Lumbar Puncture. In cases of spinal subarachnoid block, especially when this is due to a spinal tumour, the withdrawal of cerebro-spinal fluid below the level of the block by lumbar puncture may lead to a shift in the position of the tumour and a temporary or even permanent intensification of the symptoms, especially root pains and weakness. Queckenstedt's test may evoke a root pain. A careful re-examination of the patient should be made on the day following lumbar puncture, since a change in the symptoms thus produced may prove of value in the localization of the lesion.

Radiography

Radiography of the spine should be carried out in all cases of spinal compression. When this is due to disease of the vertebral column X-ray examination alone may enable the cause of the compression to be discovered. It renders visible the vertebral destruction due to tuberculous caries and other forms of osteitis, secondary carcinoma, primary vertebral neoplasm, and the changes associated with traumatic lesions. A tumour arising within the vertebral canal may by erosion lead to its diffuse enlargement, or may pass outwards through the intervertebral foramen with local destruction of bone.

Radiography after the Intrathecal Injection of Lipiodol. Lipiodol is a chemical compound containing 40 per cent. of iodine combined with poppy-seed oil. It is opaque to X-rays and was first employed in the diagnosis of spinal compression by Sicard and Forestier. It is

FIG. 66. Arrest of lipiodol in the spinal subarachnoid space in a case of adhesive arachnoiditis in the cervical region.

injected in amounts of 1 to 2 c.c. into the cisterna magna after cistern puncture (see p. 112) with the patient in a sitting position. Being heavier than cerebro-spinal fluid, it normally passes rapidly down the spinal subarachnoid space, to reach the level of the first or second sacral vertebra. When the spinal subarachnoid space is completely obstructed, the lipiodol remains arrested above the obstruction. In the presence of a partial obstruction some of the lipiodol is likely to be arrested for a time (Fig. 66). An alternative

method of employing lipiodol is to inject it by lumbar puncture, the patient being then placed with his hips at a higher level than his shoulders. In this way the lower border of the spinal obstruction may be outlined. This method should always be used when a tumour is suspected in the neighbourhood of the foramen magnum. Lipiodol is somewhat irritant, and its use should be restricted to cases in which there is evidence of spinal compression, the level of which cannot be accurately ascertained by clinical methods. Caution should always be exercised in drawing conclusions from the arrest or non-arrest of lipiodol, since in exceptional cases lipiodol may fail to be arrested by a tumour causing a spinal compression, or, on the other hand, may be arrested in the absence of any lesion discoverable at operation.

Symptoms of Spinal Compression at Different Levels.

The symptoms of spinal compression at a given level consist of (1) symptoms of a lower motor neurone lesion, that is, atrophic paralysis with diminution or loss of the tendon reflexes in the muscles innervated by the segments compressed; (2) symptoms of an upper motor neurone lesion, that is, spastic paralysis with exaggeration of the tendon reflexes, diminution or loss of the abdominal and cremasteric reflexes and an extensor plantar reflex on one or both sides below the level of the compression (in advanced cases paraplegia-in-extension in the lower limbs gives place to paraplegia-in-flexion), (3) symptoms of posterior root irritation, pain and hyperalgesia, may be present, with a segmental distribution corresponding to the segments compressed; (4) various types of sensory loss already described, with an upper level at or somewhat below the segmental level of the site of compression. The following are the principal motor and reflex disturbances resulting from compression of the spinal cord at different levels. The distribution of the sensory changes can best be ascertained from the figures on pp. 28 and 29.

(1) *The Upper Cervical Region.* Spinal compression at this level usually causes considerable pain in the neck and occiput, which is intensified by movements of the cervical spine. Pain, paraesthesiae and weakness in the upper limbs are early symptoms. Wasting may occur in both upper limbs although the cervical enlargement is not compressed. Compression of the phrenic nerves or of their nuclei may lead to diminution in the amplitude of the movements of the diaphragm. A tumour in this region may extend upwards through the foramen magnum and cause symptoms through compression of the medulla and of the lowest cranial nerves. Compression of the spinal tract and nucleus of the fifth nerve may cause relative analgesia and *thermo-anaesthesia* over the face, and the ninth, tenth, and eleventh

cranial nerves may also suffer. Signs of pyramidal compression are present in both upper and lower limbs. Postural sense and appreciation of vibration are usually impaired over one or both upper limbs.

(2) *The Fifth Cervical Segment.* Atrophic paralysis is present in the muscles innervated by this segment, namely, the rhomboids, deltoid, spinati, biceps, and supinator longus. There is spastic paralysis of the remaining muscles of the upper limbs and of the trunk and lower limbs. The biceps- and supinator-jerks are diminished or lost, but a tap on the lower end of the radius may evoke exaggerated reflex flexion of the fingers (inversion of the radial reflex (Babinski)). The triceps-jerks are preserved and may be exaggerated.

(3) *The Eighth Cervical and First Dorsal Segments.* Atrophic paralysis involves the flexors of the wrist and fingers and the small muscles of the hands. Paralysis of the ocular sympathetic may be present. The tendon reflexes of the upper limbs are preserved. There is spastic paralysis of the trunk and lower limbs.

(4) *Mid-dorsal Region.* Atrophic paralysis is confined to the intercostals innervated by the segments involved. Movements of the diaphragm are normal. There is spastic paralysis of the muscles of the abdomen and lower limbs.

(5) *Ninth and Tenth Dorsal Segments.* The lower halves of the abdominal recti are paralysed; the upper halves are normal. Consequently the umbilicus is drawn upwards when the patient raises his head against resistance. The upper abdominal reflexes are preserved, while those of the lower segments are lost. There is spastic paralysis of the lower limbs.

(6) *Twelfth Dorsal and First Lumbar Segments.* The abdominal recti are normal, but the lower fibres of obliquus internus and transversalis abdominalis are paralysed. The abdominal reflexes are preserved, but the cremasteric reflexes are diminished or lost. There is spastic paralysis of the lower limbs.

(7) *Third and Fourth Lumbar Segments.* Flexion of the hip is preserved. There are atrophic paralysis of quadriceps and the adductors of the hips, with diminution or loss of the knee-jerks, and spastic paralysis of the remaining muscles of the lower limbs, with exaggeration of the ankle-jerks and extensor plantar responses.

(8) *First and Second Sacral Segments.* Flexion of the hip, adduction of the thigh, extension of the knee, and dorsiflexion of the foot are preserved. There are atrophic paralysis of the intrinsic muscles of the foot and of the calf muscles, and spastic paralysis of flexion of the knee and of all muscles moving the hip-joint, except the flexors and adductors. The knee-jerks are preserved; the ankle-jerks and plantar reflexes are lost. The anal and bulbo-cavernosus reflexes are preserved.

(9) *Third and Fourth Sacral Segments.* The large bowel and bladder are paralysed and retention of urine and faeces occurs, due to the uninhibited action of the internal sphincters. The external sphincters are paralysed and the anal and bulbo-cavernosus reflexes are lost. The motility and reflexes of the lower limbs are normal.

Compression of the Cauda Equina.

Compression of the cauda equina is most frequently due to a neoplasm, but the nerve-roots may be compressed by fat in cases of spina bifida occulta, by the constriction of a fibrous band (Léri), or by chronic arachnoiditis. An important source of compression is a displaced intervertebral disk, usually that between the fourth and fifth lumbar vertebrae, less often that between the fifth lumbar and first sacral or between the third and fourth lumbar. Rupture and herniation of part of the disk may be caused by *lifting* a heavy object, a fall, or a strain. The clinical picture is a variable one, depending upon the site and extent of the source of compression. A small tumour may for a long time compress only one or two roots on one side. A large and massive growth may involve the whole of the cauda. For anatomical reasons the *lower* roots are more likely to be compressed than the upper, since they suffer alone when a growth is situated in the lowest part of the spinal canal and they are also implicated, together with the upper roots, by tumours at a higher level.

In almost all cases of compression of the cauda equina by tumour, pain is the earliest symptom. It is usually located in the lumbar or sacral regions of the spine. It is usually a dull, aching pain and is liable to be exacerbated by jerky movements, coughing, and sneezing. Less frequently the pain is referred to one or both lower limbs in the distribution of certain of the lower spinal roots and may also be referred to the bladder or rectum.

Motor symptoms consist of atrophic paralysis, the distribution of which depends upon the roots affected. Most frequently there is paralysis of the muscles below the knee, though the tibialis anticus may escape, and of the hamstrings and glutei. In such cases the ankle-jerks are diminished or lost, and the plantar reflexes may also be unelicitable; but the knee-jerks are often preserved.

The distribution of the sensory loss also depends upon which posterior roots are involved. Compression of the lower sacral roots leads to a characteristic saddle-shaped area of anaesthesia and analgesia extending over the buttocks and back of the thighs. Compression of the upper sacral and fifth lumbar roots produces an area of sensory loss over the foot and over the back and outer aspect of the leg. When the lowest sacral segments are involved, though the

external genitals are anaesthetic and the patient may be unaware of the passage of a catheter through the urethra, some sensibility usually remains in the bladder, so that the patient is aware of its distension, and cystitis may give rise to pain.

Disturbance of function of the bladder and bowel is usually a late development. Compression of the third and fourth anterior and posterior sacral roots interrupts the reflex arc upon which evacuation of the bladder and rectum depends. The result is retention of urine and faeces due to the unopposed contraction of the internal sphincters, although the external sphincters are paralysed. Impotence occurs in the male. When the lowest sacral roots are compressed the anal and bulbo-cavernosus reflexes are lost, but these will be preserved as long as these roots escape.

Trophic symptoms are not uncommon in the lower limbs, which are frequently cold and cyanosed and tend to become oedematous if they are allowed to hang down. Slight injuries over the analgesic areas are apt to lead to sores which do not quickly heal and which leave permanent scars.

The symptoms of a displaced intervertebral disk in the lumbar region are: pain of a sciatic distribution, scoliosis, loss of the normal lordosis, and rigidity of the lumbar spine, and some wasting of the painful limb with loss of the ankle-jerk. Radiography in the prone posture after the injection of 5 c.c. of lipiodol by lumbar puncture usually demonstrates a filling defect corresponding to the anteriorly placed rounded nodule.

The diagnosis of a tumour of the cauda equina from a tumour of the conus medullaris is often difficult and may be impossible. If, however, in spite of paralysis of the bladder and rectum, the anal and bulbo-cavernosus reflexes are preserved and if sensory loss is of the dissociated type, that is, if sensibility to pain, heat, and cold is lost, while that to light touch is preserved, it is likely that the lesion involves the conus rather than the roots. The presence of an extensor plantar response on one or both sides indicates that the spinal cord is compressed at least as high as the fifth lumbar segment.

Diagnosis.

The diagnosis of spinal compression involves four stages: (1) Spinal compression must be distinguished from other lesions which may give rise to similar symptoms. (2) When the existence of spinal compression has been established, its segmental level must be determined. (3) An attempt should then be made to decide whether the compression is extradural, extramedullary, or intramedullary; and (4) what is its pathological nature.

(1) *Diagnosis from other Disorders.*

When the earliest symptom of spinal compression is pain, it is liable to be confused with visceral disorders of which pain is a prominent symptom, for example, pleurisy, angina pectoris, cholecystitis, gastric and duodenal ulcer, and renal calculus. This error can only be avoided by a thorough examination of the nervous system, which will usually yield some indication of a lesion of the spinal cord, and also by the absence of physical signs of visceral disease. When spinal compression causes paraplegia it requires to be distinguished from other disorders of which this may be a prominent symptom, especially spinal syphilis, disseminated sclerosis, syringomyelia, and amyotrophic lateral sclerosis. On clinical grounds this distinction can usually be made with considerable certainty, but the diagnosis can only be clinched by an examination of the cerebro-spinal fluid which includes Queckenstedt's test. The changes in the fluid characteristic of spinal compression are unmistakable and are usually present by the time that symptoms are sufficiently severe to give rise to confusion with the disorders mentioned. It must always be remembered that *spinal tumour may coexist with syphilis*, and the presence of a positive Wassermann reaction in the blood and even in the cerebro-spinal fluid must not be taken as conclusive evidence that the patient's symptoms are due to syphilis. Clinical evidence suggesting spinal compression, especially if associated with the changes characteristic of this in the spinal fluid should lead to exploration of the cord in spite of the positive Wassermann reaction.

(2) *Localization of Segmental Level.*

In the localization of the segmental level of spinal compression segmental symptoms, especially atrophic paralysis and root pains and hyperalgesia, are of the first importance. Next in value is the upper limit of the area of sensory loss, though this is not always easy to define. When it can be accurately determined the segmental level of the upper limit of the area of analgesia may be taken as indicating the lowest segment compressed. In the small proportion of cases in which clinical methods fail to yield accurate evidence of the segmental level of the compression, this can usually be established by radiography following the intracisternal or lumbar injection of lipiodol.

Relationship of Spinal Segments to Vertebrae. Since the spinal cord terminates at the level of the lower border of the first lumbar vertebra, spinal segments do not correspond numerically with the vertebral arches by which they are enclosed. Having localized a source of compression in terms of spinal segments, the surgeon requires to

know beneath which laminal arch he may expect to find it. To ascertain which spinal segment is related to a given vertebra:

For the cervical vertebrae, add 1.

For dorsal 1–6, add 2.

For dorsal 7–9, add 3.

The tenth dorsal arch overlies lumbar 1 and 2 segments.

The eleventh dorsal arch overlies lumbar 3 and 4.

The twelfth dorsal arch overlies lumbar 5.

The first lumbar arch overlies the sacral and coccygeal segments.

It must be remembered that owing to the obliquity of the lower dorsal spinous processes a spinous process in this region is situated at the level of the body of the vertebra below.

(3) The Relationship of the Source of Compression to the Cord.

Angular deformity of the spine and radiographic evidence of vertebral destruction indicate clearly that vertebral disease is responsible for the spinal compression. In the absence of such evidence the differentiation of extradural, extramedullary, and intramedullary sources of spinal compression is often difficult and may be impossible. In extradural compression root pains not uncommonly occur early and symptoms of spinal compression are usually bilateral and symmetrical in their development. Motor symptoms usually appear first, to be followed later by sphincter disturbances, and sensory changes are frequently late. The protein content of the cerebro-spinal fluid is often not greatly increased and usually lies between 40 and 150 mg. per c.c. The distinction between extramedullary and intramedullary compression is often impossible before operation. The early onset of unilateral root pains and the development of symptoms indicating that compression is mainly exerted upon one-half of the cord favour an extramedullary source of compression. In such cases, moreover, blockage of the spinal subarachnoid space tends to occur early and the protein content of the spinal fluid is usually high. In cases of intramedullary compression root pains are less frequent and motor symptoms are usually bilateral. An area of dissociated sensory loss extending over a series of segments just below the level of the lesion is suggestive of an intramedullary growth. Subarachnoid blockage occurs later and the protein content of the fluid is usually lower in the case of intramedullary than in the case of extramedullary compression.

(4) Diagnosis of the Cause.

(i) Vertebral Disease. When spinal compression is due to vertebral disease there are usually considerable pain in, and rigidity of, the

spine; angular deformity is common and radiographic evidence of vertebral destruction will usually be found. *Tuberculous caries* is to be suspected when these symptoms are present in a young patient who shows evidence of infection, such as pyrexia and sweating, with possibly in addition signs of a tuberculous abscess or of a tuberculous focus elsewhere, but it may occur at any age and without general symptoms. *Secondary carcinoma* of the vertebral column is usually seen in middle-aged patients. The onset of the spinal symptoms is often rapid and attended by considerable pain. There is often a history of an operation for carcinoma and, in the absence of this, careful clinical and radiological examination usually enable the primary growth to be found. The diagnosis of other forms of vertebral disease, for example, myelomatosis and osteitis deformans of Paget, can usually only be established radiographically. When the former is suspected the urine should be examined for Bence-Jones proteose.

(ii) *Spinal Tumour.* Spinal tumour is to be suspected in cases in which there is a gradual onset and a slowly progressive development of symptoms of spinal compression, in the absence of evident disease of the vertebral column. It is usually impossible to anticipate the nature of the spinal tumour, but careful search should be made for cutaneous pigmentation and other symptoms of neurofibromatosis, which may be associated with an intrathecal neurofibroma.

(iii) *Meningitis.* It is often impossible to diagnose either hypertrophic pachymeningitis or arachnoiditis before operation A history of infection or of injury to the vertebral column should suggest the possibility of arachnoiditis while the occurrence of multiple levels of segmental sensory disturbance, and a patchy or streaky arrest of lipiodol is in favour of this.

Such rare causes of spinal compression as Hodgkin's lymphogranulomatosis, chloromatosis or leukaemic deposits, and parasitic cysts can be suspected only when clinical examination reveals evidence of the disease elsewhere.

Prognosis.

General Considerations.

The prognosis of compression of the spinal cord depends upon (1) the nature of the source of compression and the extent to which it can be relieved, (2) the severity and duration of the disturbance of function when the patient comes under observation, and (3) the level of the cord compressed. The influence of the nature of the compressing agent upon prognosis is further considered below. The more severe the interruption of conduction in the cord, the less likely is recovery to be complete. Hence the development of paraplegia-

in-flexion, which indicates a severe degree of interruption of the cord, is of bad prognostic import and little functional improvement can be expected in such cases. The longer symptoms of compression have been present, the less complete is recovery likely to be, though even when such symptoms as spastic weakness of the lower limbs have been present for two years, a remarkable degree of recovery may occur. The outlook is best when the site of compression is situated in the middle or lower dorsal regions. When the cervical cord is compressed the proximity of the spinal centres innervating the diaphragm adds to the risk both of the compression itself and of operations upon this region. Compression of the lumbo-sacral region and cauda equina is especially liable to lead to disturbance of function of the bladder and bowel, and hence there is a high incidence of infection of the urinary tract in such cases. In all cases of spinal compression the presence of infection of the urinary tract and of severe bed-sores adds to the gravity of the prognosis.

Tuberculous Spinal Osteitis.

The mortality rate of tuberculous caries of the spine ranges in different series from 20 to 50 per cent. of cases. When modern methods of treatment are employed, however, it probably lies between 10 and 20 per cent. Spinal compression naturally increases the risk of death, but about 70 per cent. of patients with paraplegia recover completely. Others are left with some spastic weakness of the lower limbs. The prognosis both as to life and as to recovery of function is better in children than in adults. The sudden development of paraplegia rapidly becoming complete is usually due to 'concertina' collapse of a vertebral body or to thrombosis of vessels supplying the cord, and in both conditions the outlook is poor. When paraplegia-in-flexion is present there is no hope of recovery.

Secondary Carcinoma of the Vertebrae.

Few patients survive more than nine months after the development of symptoms indicating the presence of metastatic carcinomatous deposits within the vertebral column, death occurring either as a direct result of disturbance of function caused by the primary growth, or from cachexia due to widespread metastases.

Spinal Tumour.

The prognosis of spinal tumour depends primarily upon the extent to which the growth can be removed. Accordingly the outlook is much better in the case of extramedullary tumours, a large proportion of which can be removed completely, than when the tumour is intramedullary. Few intramedullary tumours can be successfully

removed without considerable damage to the spinal cord. Improvements in surgical technique, however, are likely to add to the proportion which are operable. The mortality rate of operations for spinal tumours is under 10 per cent in the best hands. A considerable functional improvement may be expected to follow the successful removal of a spinal tumour in all but the most advanced cases, even when symptoms of compression have been present for several years. Improvement, however, may be slow and may be expected to continue for a year or more after operation.

Meningitis Circumscripta Serosa.

The response to operation is often disappointing and only about 30 per cent. recover.

Treatment.

The treatment of compression of the spinal cord involves (1) the appropriate treatment of the source of the compression, and (2) when paraplegia is present, adequate care of the paralysed limbs, the skin, the urinary tract, and the bowels, along the lines laid down on p. 610, for upon the careful treatment of the paraplegia may depend not only the patient's life but also the rate at which recovery of function occurs.

Tuberculous Spinal Osteitis.

A patient suffering from tuberculous caries of the spine requires rest with hyperextension of the spine, in order to take the weight of the upper part of the body from the damaged vertebrae and so prevent increase of the deformity. Immobilization is obtained by means of a suitable frame or by a plaster bed. Every effort must be made to improve the patient's general health and promote resistance to the infection. For this purpose fresh air and sunlight, either natural or artificial, are invaluable. The diet should be ample and augmented by cod-liver oil or by one of the proprietary preparations rich in vitamins, and iron and strychnine may be given.

For the indications for the operations of costotransversectomy and spinal fusion reference should be made to text-books of surgery and to Seddon's (1934–5) paper. Laminectomy is rarely desirable, since most patients rapidly improve on the treatment described. An exploratory operation, however, may be carried out when paraplegia has continued unimproved after several months of treatment or when a sudden increase in its severity occurs; for example, the conversion of paraplegia-in-extension to paraplegia-in-flexion, which may indicate the compression of the cord by bone.

Secondary Carcinoma of Vertebrae.

Treatment of this condition can only be palliative, and morphine
should be given in doses adequate for the relief of pain. X-ray
irradiation of the affected region of the spine may also give relief.
When pain is very severe and the patient's general condition is
sufficiently good, chordotomy may be carried out, the ascending
pain fibres in the spino-thalamic tract being interrupted at least six
spinal segments above the uppermost root compressed.

Spinal Tumour.

Laminectomy should be performed, and when the tumour is
extradural or extramedullary it should be as far as possible removed.
For the treatment of intramedullary tumours Elsberg recommends
incising the posterior aspect of the cord, slightly to one side of the
median septum, and allowing the tumour to extrude itself, a second
operation being performed a week later for the removal of the
extruded portion. It is, however, sometimes possible to dissect out
and remove an intramedullary tumour without serious damage to
the cord. When a spinal tumour for any reason cannot be removed,
the operation of laminectomy may lead to a temporary improvement
by diminishing the pressure upon the cord. X-ray irradiation may
be of value as an accessory method of treatment following operation,
especially for intramedullary tumours. Little is at present known
concerning the value of radium in the treatment of spinal tumour.

Meningitis.

When spinal pachymeningitis is of long standing, it leads to soften-
ing of the spinal cord through interference with its vascular supply.
In such cases little benefit can be expected to follow operation. At
an earlier stage, however, when the symptoms are mainly due to
constriction of the cord, improvement may follow laminectomy and
removal of granulation tissue. When arachnoiditis is found at
operation, an attempt should be made to free the cord from adhesions.

The after-treatment of patients suffering from spinal compression
and who have undergone laminectomy, should include massage and
passive movements of the paretic limbs and re-educational exercises,
in order to promote functional recovery.

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8. SYRINGOMYELIA

Synonym: Status dysraphicus

Definition: A chronic disease characterized pathologically by the presence of long cavities, surrounded by gliosis, which are situated in relation to the central canal of the spinal cord and frequently extend up into the medulla (syringobulbia). The principal clinical features are areas of cutaneous analgesia and thermo-anæsthesia, with

Fig 67. Syringomyelia: spinal cord. Cavitation surrounded by gliosis.

preservation of the appreciation of light touch and postural sensibility, muscular wasting, and trophic changes, especially in the upper limbs, and symptoms of pyramidal degeneration in the lower limbs.

Pathology.

The pathological changes characteristic of syringomyelia are most frequently situated in the lower cervical and upper thoracic regions of the spinal cord. Extension to the medulla is common, and the process may reach the pons or even as high as the internal capsule (Russell). A thoracico-lumbar and lumbo-sacral incidence is less frequent.

The affected region of the cord is enlarged, mainly in the transverse plane (Fig. 67). In some cases the enlargement is sufficient to cause erosion of the bones of the spinal canal. Transection of the cord reveals a cavity surrounded by a zone of translucent

gelatinous material. The cavity, which often possesses diverticula, contains clear or yellow fluid. The pathological process appears to originate most frequently at the base of one posterior horn of the grey matter of the spinal cord. Less frequently it begins in the middle line in the grey matter, near the central canal. Exceptionally this canal itself appears dilated. In the medulla the region affected is the *posterolateral part, in the neighbourhood of the spinal nucleus of the trigeminal nerve and the nucleus ambiguus*. Fissures may radiate from the fourth ventricle into this region. Microscopically the gelatinous material lining the cavity contains glial cells and fibres.

The expansion of the cavity and surrounding gliosis lead to compression of the anterior horns of the grey matter, thus causing atrophy of the anterior horn cells and degeneration of their axones in the anterior roots and peripheral nerves. Compression of the long ascending and descending tracts of the cord occurs somewhat later and leads to secondary degeneration, which is most marked in the pyramidal tracts, the spino-thalamic tracts, and the posterior columns. Haemorrhage into a syringomyelic cavity constitutes one form of haematomyelia.

Aetiology.

There is general agreement that in most cases syringomyelia is based upon a congenital abnormality and is the outcome of abnormal closure of the central canal of the spinal cord in the embryo It has been suggested that incomplete closure leaves cavities around which a secondary gliosis develops and alternatively that during closure spongioblasts are included in the region of the central canal and that these later form glial tissue which undergoes cavitation Disturbances of the blood-supply are probably of secondary importance in aetiology and there is no good reason to suspect that infection plays any part in causation. Trauma has been held to be of aetiological importance It has been suggested that intra-uterine haemorrhage within the cord may form the starting-point of syringomyelia, though there is no evidence of this Occasionally also in adult life the symptoms of syringomyelia are held to date from an accident. It is probable, however, that in such cases the trauma, if it possesses any significance, is not the primary cause of syringomyelia, but merely excites a latent abnormality into activity.

A familial and even a hereditary incidence of syringomyelia is well established, though it is exceptional Multiple cases have been described in siblings, but the condition is usually sporadic. In this connexion it is interesting that congenital abnormalities have been observed in otherwise normal relatives of a patient suffering from

syringomyelia. The occasional familial occurrence of syringomyelia relates it to myelodysplasia (see p. 651), and the not uncommon occurrence of spina bifida, both in patients with syringomyelia and in their relatives, affords support for the theory that syringomyelia is based upon defective closure of the spinal cord.

Although in most cases syringomyelia possesses the congenital pathological basis already described, cavitation may occur within the spinal cord as a result of intramedullary tumour, the cavity developing either within the tumour, or outside it in a manner similar to that in which cysts are produced by cerebellar angioblastomas It is not uncommon also for a spinal tumour to develop in a patient already suffering from syringomyelia.

The age of onset of symptoms in syringomyelia ranges between 10 and 60. Usually it lies between 25 and 40. Males suffer more frequently than females in the proportion of about three to one.

Symptoms.

The symptoms of syringomyelia are readily interpreted as the putcome of the progressive lesion in the central region of the spinal cord.

Mode of Onset.

The onset is extremely insidious. Wasting and weakness of the small muscles of the hands are the commonest early symptoms, but the patient may notice the loss of feeling in the hands or the resulting injuries. Less often pain or trophic lesions first attract attention.

Sensory Symptoms.

At the earliest stage there is an elongated cavity surrounded by gliosis, situated in most cases at the base of one posterior horn of grey matter and extending longitudinally through several segments, usually in the lower cervical and upper thoracic segments of the cord. The effect of such a lesion is to interrupt on one side the decussating sensory fibres derived from several consecutive posterior roots. Since the fibres which decussate shortly after entering the cord are those which conduct impulses concerned in the appreciation of pain, heat, and cold, these forms of sensibility are impaired while other forms are preserved. This is the dissociated sensory loss described by Charcot and is usually first observed along the ulnar border of the hand, forearm, and arm, and upper part of the chest and back on one side. When the lesion is centrally situated from the first or has extended from one side of the cord to the other, the area of dissociated sensory loss is bilateral. As the lesion extends upwards and downwards in the cord, the area of sensory impairment extends to the radial sides of the upper limbs and to the neck and downwards over

the thorax, exhibiting at this stage a distribution *en cuirasse*. The areas over which appreciation of pain, heat, and cold are first impaired, and later lost, are not always, nor even usually, coterminous, but any one may be more extensive than the others   When the lesion reaches the upper cervical segments it begins to involve the spinal tract and nucleus of the trigeminal nerve, which receives fibres conducting impulses concerned in the appreciation of pain, heat, and cold from the face. Progressive destruction of these fibres causes extension of the area of dissociated sensory loss in a concentric manner from behind forwards on the face, sensibility on the tip of the nose and upper lip being last affected. Exceptionally the disorder begins in the medulla, in which case sensibility is first impaired on the face.

The progressive extension of the spinal lesion later causes compression of the spino-thalamic tracts on one or both sides, leading to loss of appreciation of pain, heat, and cold over the lower parts of the body. It is not uncommon to find an area of normal sensibility over the abdomen intervening between the area of thoracic anaesthesia due to interruption of the decussating fibres and the area of sensory loss on the lower limbs due to compression of the spino-thalamic tracts. Sensation over the posterior aspects of the lower limbs is usually affected last. When the spino-thalamic tract is compressed at the level of the medulla, appreciation of pain, heat, and cold is impaired or lost over the whole of the opposite half of the body. The posterior columns usually the last of the sensory pathways to suffer, but in the late stages appreciation of posture, passive movement, and vibration is likely to be impaired, especially in the lower limbs, and there may be extensive anaesthesia to light touch.

Thermo-anaesthesia may be detected by the patient, owing to the fact that hot water no longer feels hot over the affected parts of the body, and his analgesia exposes him to injuries, especially burns of the fingers, which he does not notice at the time, because they are painless. Spontaneous pains, though usually absent, are sometimes troublesome, and the patient may describe burning, aching, or shooting pains which sometimes closely resemble the lightning pains of tabes. Such pains in one side of the face or in the upper limb may be the first symptom. When the lesion begins in the thoracico-lumbar or lumbo-sacral regions of the cord the dissociated loss has a corresponding distribution.

Optic atrophy is exceptional, but has occasionally been described.

Motor Symptoms.

The earliest motor symptoms are usually muscular weakness and wasting due to atrophy of the anterior horn cells produced by

compression. Since the lesion usually begins in the cervico-thoracic region of the cord, muscular wasting usually first appears in the small muscles of the hands. It may be bilateral from the beginning, or one hand may suffer before the other. As the lesion extends, the muscular wasting spreads to involve the forearms and later the arms, shoulder girdles, and upper intercostals. It is often slight and is never as severe as is seen in advanced cases of progressive muscular atrophy. Fibrillation is usually absent. Contractures may develop, especially in the muscles of the hand and forearm. Extension of the lesion to the postero-lateral part of the medulla not uncommonly involves the nucleus ambiguus, causing paresis of the soft palate, pharynx, and vocal cord. The other motor functions in which the cranial nerves are concerned are less frequently affected, though I have seen paralysis of the mandibular muscles, external rectus, facial muscles, and soft palate on one side as a result of haemorrhage into a syringo-myelic cavity in the pons and medulla. The tongue is occasionally involved. Nystagmus is commonly present in syringomyelia. It is usually rotary in character and has been ascribed to involvement of the vestibular and cerebellar connexions within the brain-stem. Paralysis of the ocular sympathetic on one or both sides is not uncommon and leads to small and often irregular pupils, with ptosis and slight enophthalmos. The reaction to light is preserved.

Compression of the pyramidal tracts in the spinal cord causes weakness, with slight spasticity and extensor plantar responses in the majority of cases in the later stages. The loss of power, however, is rarely severe. The tendon reflexes are exaggerated in the lower limbs and may be either exaggerated, diminished, or lost in the upper limbs, depending upon the predominance of upper or lower motor neurone lesions. The sphincters are usually little affected.

Trophic Symptoms.

Trophic symptoms are conspicuous. True hypertrophy involving all the tissues may be present in one limb or one-half of the body. Loss of sweating or excessive sweating may occur, usually over the face and upper limbs. Excessive sweating may be spontaneous or may be excited reflexly when the patient takes hot or highly seasoned food. Twenty per cent. of patients exhibit osteoarthropathy—Charcot's joints. The shoulders and elbows are most frequently affected, less often the joints of the hands, the temporo-mandibular joint, the sterno- and acromio-clavicular joints, and the joints of the lower limbs. Atrophy and decalcification of the bones in the region of the joints with erosion of joint surfaces are the usual radiographic findings, the hypertrophic varieties of arthropathy being unusual (Fig. 68) The development of the joint changes is not associated

with pain. The affected joint is often enlarged and movement evokes loud crepitus but is painless. The long bones are frequently brittle Trophic changes in the skin include cyanosis, probably due to a vasomotor paralysis, hyperkeratosis, and thickening of

FIG. 68 Syringomyelia· Charcot elbow.

the subcutaneous tissues, leading to a swelling of the fingers described as 'la main succulente'. The analgesia, as already described, renders the patient exceptionally liable to minor injuries, and the poor nutrition of the hands delays healing. Ulceration, whitlows, and necrosis of bone are not uncommon Gangrene rarely occurs. The scars of former injuries are usually evident upon the palmar surface of the fingers

Syringobulbia.

The medulla may be involved by upward extension from the spinal cord, or may be the initial site of the disorder. In the latter case the onset of symptoms may be sudden or gradual. Trigeminal pain, vertigo, facial, palatal, or laryngeal palsy or wasting of the tongue

may be the presenting symptom. The physical signs of syringobulbia have been described above.

Morvan's Disease.

Morvan, in 1883, described the occurrence of painless whitlows upon the fingers of both hands (Fig. 69). Similar lesions have also been

FIG. 69. A case of Morvan's disease, with loss of the terminal portions of the fingers.

described on the feet, and cutaneous ulceration may occur. Pain is not always absent. These trophic lesions are associated with muscular wasting of the hands and dissociated sensory loss over the upper extremities and sometimes over the feet. Morvan's disease is a rarity and is now usually regarded as a form of syringomyelia in which trophic symptoms are unusually prominent, although neuritis has been described in the peripheral nerves in one case. It is possible that some examples of Morvan's disease are due to myelodysplasia rather than to syringomyelia.

Associated Abnormalities.

A large number of abnormalities have been described in association with syringomyelia, occurring either in affected individuals or in members of their families. Bremer has recently drawn attention to the following anomalies: deformities of the sternum, kyphoscoliosis, a difference in the size of the breasts, increase in the ratio between

arm and body length, acrocyanosis of the hands, curved fingers, circumscribed sensory disturbances, enuresis, and so-called stigmas of degeneracy, such as anomalies of the hair and ears Common abnormalities which may be added to Bremer's list include cervical rib, spina bifida, and pes cavus, while acromegaly is an occasional complication. Light brown pigmentation either in spots or diffuse sheets often with a segmental distribution is not uncommon.

The Cerebro-spinal Fluid.

The cerebro-spinal fluid usually shows no abnormality. Exceptionally, however, the enlargement of the spinal cord may be sufficiently great to cause obstruction of the subarachnoid space, and when this occurs the fluid may present the features associated with spinal subarachnoid block, especially the high protein content, with or without xanthochromia. In such cases blockage of the spinal subarachnoid space may be demonstrable by Queckenstedt's test.

Diagnosis.

There is little difficulty in making a diagnosis of syringomyelia when the disorder is advanced, since the association of wasting and trophic lesions of the hands with extensive dissociated sensory loss, and symptoms of pyramidal lesions in the lower limbs is highly distinctive. The diagnosis is much more difficult in the early stages Intramedullary tumour of the spinal cord may closely simulate syringomyelia. As a rule, however, it progresses more rapidly and blockage of the spinal subarachnoid space, with resulting changes in the cerebro-spinal fluid, is likely to occur much earlier. The same is true of extramedullary spinal tumours with the addition that pain is usually a more prominent symptom in the case of this lesion than in syringomyelia. Haematomyelia, though it may produce similar symptoms to syringomyelia, develops acutely. Moreover, when the cervical enlargement is the site of haematomyelia, impairment of all forms of sensibility, including appreciation of light touch and passive movement, is much commoner than in syringomyelia, except in the very late stages It must be remembered that haemorrhage into a syringomyelic cavity constitutes one form of haematomyelia. Progressive muscular atrophy may simulate syringomyelia when it begins with wasting of the small muscles of the hands, especially when the pyramidal fibres to the lower limbs are simultaneously involved. Sensory loss, however, is absent as a rule, and if present is slight and transitory. In progressive muscular atrophy muscular fibrillation is almost constantly present and is frequently widespread, whereas in syringomyelia it is exceptional. Cervical rib may cause symptoms which resemble those of the early stage of syringo-

myelia and the distinction between the two is rendered difficult by the fact that they may coexist. Pain along the ulnar border of the hand and forearm is a common result of cervical rib, but rare in syringomyelia, and it is usual for the latter condition to come under observation at a stage at which sensory loss possesses an extent larger than can be attributed to a cervical rib. Peroneal muscular atrophy is distinguished from syringomyelia by the fact that muscular wasting of the lower limbs precedes that of the upper. The trophic symptoms of Raynaud's disease may simulate syringomyelia, but the dissociated sensory loss is absent in the former, while in the latter the attacks of blanching of the fingers observed in Raynaud's disease do not occur.

Syringobulbia presents little difficulty in diagnosis when the medullary lesion is an upward extension of cervical syringomyelia. When it occurs alone, however, it must be distinguished from other lesions of the medulla. Thrombosis of the posterior inferior cerebellar artery, which usually leads to sensory loss similar to that found in syringobulbia, is distinguished by its acute onset. Tumours of the medulla may closely simulate syringobulbia, especially as symptoms of increased intracranial pressure may be slight or absent, but extension to the pons, leading to paralysis of the external rectus or of conjugate ocular deviation and to facial paresis, is common in the case of medullary tumours and rare in syringobulbia. Progressive bulbar palsy is distinguished by the absence of sensory loss.

Prognosis.

The course of syringomyelia is progressive, though progress is frequently slow and remissions may occur, so that the patient's condition may remain unchanged for years. A sudden intensification of symptoms may be produced by haemorrhage into a syringomyelic cavity, and occasionally distension of the spinal cord may become so marked as to produce a complete transverse lesion leading to paraplegia. Both of these events, however, are exceptional, and sufferers from syringomyelia frequently live many years, death occurring either from bulbar paralysis, leading to broncho-pneumonia, or from some other intercurrent infection.

Treatment.

The most effective treatment of syringomyelia is X-ray irradiation of the affected region of the spinal cord and medulla, which was first introduced in 1905. Almost all the symptoms may be considerably relieved. Pain may be much diminished, though temporarily intensified after each treatment. The area of sensory loss may be reduced and muscular power improved. Trophic changes respond especially well and improvement in the circulation of the extremities may be

expected, with diminution of hyperkeratosis. The healing of trophic lesions is accelerated, and they are less liable to occur after treatment than previously. Although the majority of patients respond well to X-ray irradiation, a few prove refractory. Surgical treatment may exceptionally be required, especially for the relief of severe pain or when there is evidence of blockage of the subarachnoid space. In such cases the affected region of the spinal cord may be decompressed by laminectomy and additional relief from pressure may be obtained by incising the posterior aspect of the cord. This operation, however, has a high mortality rate, as patients with syringomyelia stand anaesthetics badly and there is considerable risk that paralysis of the diaphragm may result from post-operative oedema of the cord Massage, passive movements, and re-educational exercises are helpful in improving nutrition of the limbs and in maintaining voluntary power. Trophic lesions will require appropriate local treatment.

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9. MYELODYSPLASIA

'Myelodysplasia' is the term employed by Fuchs to describe a condition which he believes to be due to incomplete closure of the neural tube in the embryo It is frequently familial and sometimes hereditary and in some respects resembles syringomyelia. Unlike the latter condition, however, it is non-progressive. The symptoms usually indicate a disturbance of function of the lumbo-sacral region

of the spinal cord, though other parts may be affected. Myelodysplasia is closely related to spina bifida, with which in fact it may be associated. In the former, however, the spinal cord appears to be principally affected, in the latter the cauda equina.

Lumbo-sacral myelodysplasia has been held responsible for a variety of disturbances which are frequently familial. The following are the principal symptoms: impairment of sphincter control, leading especially to enuresis; deformities of the feet, for example, pes cavus and syndactylism of the toes; wasting of the muscles below the knees, with impairment of the ankle-jerks; dissociated sensory loss of a syringomyelic character over the legs; and trophic disturbances of the feet, such as delayed healing of wounds, chronic ulceration, and gangrene. Spina bifida is sometimes, but not always, present.

Hereditary gangrene of the fingers has been attributed to myelodysplasia of the cervical region of the spinal cord.

Myelodysplasia is distinguished from syringomyelia by the fact that it is frequently familial, by its non-progressive character, and by its predominant incidence upon the lower limbs. Other causes of muscular wasting and of trophic lesions of the feet must be excluded, especially peroneal muscular atrophy, polyneuritis, tabes, and gangrene of vascular origin.

The spinal defect upon which the symptoms depend is non-progressive, but there is a tendency for trophic lesions to occur and the patient may be progressively crippled by these. Death may occur from septicaemia.

X-ray irradiation of the affected region of the spinal cord may be tried, but otherwise treatment is symptomatic.

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10. SPINA BIFIDA

Synonym: Rachischisis.

Definition: Incomplete closure of the vertebral canal, which is usually secondary to a similar anomaly of the spinal cord.

Aetiology and Pathology.

In the early embryo the nervous system is represented by the neural groove, the lateral folds of which unite dorsally to form the neural tube. An arrest in this process of development leads to defective closure of the neural tube, associated with a similar defect

in the closure of the bony vertebral canal—spina bifida. A number of varieties of spina bifida are described, differing in respect of the nature and severity of the spinal defect In the severe forms a sac protrudes through the vertebral opening, which yields an impulse on crying and coughing, and compression of which in the infant increases the tension of the fontanelle The sac may contain meninges only—meningocele, in more severe cases it contains both meninges and the flattened, opened spinal cord—myelocele or meningo-myelocele In such cases, when the cutaneous covering is incomplete, there may be a discharge of cerebro-spinal fluid. Very rarely the central canal of the cord is closed but dilated—syringomyelocele In the least severe cases there is no protrusion, but a defect in the laminal arches may be palpable as a depression, which is sometimes covered by a dimple or a tuft of hair (spina bifida occulta) Spina bifida is not uncommonly hereditary.

The commonest site of spina bifida is the lumbo-sacral region Occasionally it is found in the dorsal region, very rarely in the cervical In lumbo-sacral spina bifida the spinal cord frequently retains its foetal length and extends as low as the sacrum. The flattened cord and nerve-roots are often embedded in a pad of fat. Léri has described the occurrence in association with spina bifida of a fibro-cartilaginous band compressing the cauda equina Spina bifida is not uncommonly associated with other congenital abnormalities such as hydrocephalus due to the Arnold-Chiari malformation of the medulla, occipital meningocele, hare lip, and cleft palate There may be general physical hypoplasia, with some degree of mental defect Severe degrees of spina bifida are incompatible with survival, the victim being stillborn or surviving birth only a short time. Paralysis of the lower limbs is usually present in the latter case.

Spina Bifida Occulta

Spina bifida occulta may give rise to no symptoms and may be an accidental discovery in the course of a routine examination. It is of considerable clinical importance, however, since it sometimes gives rise to symptoms, the cause of which is not immediately evident. In such cases a careful investigation of the history usually shows that symptoms were present at an early age, though improvement may *have occurred, to be followed by a relapse in early adult life. Such* a relapse may be due to the effect of growth in causing tension upon the lower end of the cord and cauda equina, which are anchored at an abnormally low level, or to the compression of these structures by fat or by the band described by Léri. The symptoms are those of a chronic lesion of the cauda equina, though frequently one function is more conspicuously affected than others.

Weakness of the lower limbs may be present. Frequently it has been noted that the patient was slow in learning to walk and walked clumsily at first. Muscular wasting and weakness may be present in the muscles below the knees, with impairment or loss of the ankle-jerks and contracture of the calf muscles, leading to pes cavus. Sensation may be impaired over the cutaneous areas innervated by the lowest sacral segments, leading to the characteristic saddle-shaped area of analgesia over the buttocks and posterior surface of the thighs. Pain is usually inconspicuous. Sphincter disturbances are often prominent. Enuresis may be present, either constantly or intermittently, from infancy. It is frequently stated that the patient was late in gaining control over the bladder as a child, and this may never have become complete. Frequently nocturnal enuresis is associated with precipitate micturition by day. Less frequently retention of urine develops. Jancke has described a sibship in which enuresis occurred in several generations and was associated with spina bifida in those members who were examined radiographically. The rectal sphincter is less often affected, though constipation, or less frequently, incontinence of faeces may occur. Impotence may be present in the male, either from the beginning of sexual life or after a period of normal potency. Trophic changes are conspicuous in some cases and are rarely altogether lacking. In milder cases the feet are usually cold and cyanosed, and cutaneous injuries are slow in healing and tend to lead to ulceration, not only of the feet but also of the analgesic skin of the buttocks and thighs. Gangrene of the toes may occur and arthropathies have been described in the feet. Less common abnormalities include global atrophy of one lower limb, trophoedema of one lower limb (Léri), sclerodermia, melanoleucodermia, and cutaneous naevi.

Cervical spina bifida occulta may be associated with symptoms resembling syringomyelia in the upper limbs, with wasting and trophic disturbances in the hands, and dissociated sensory loss.

The cerebro-spinal fluid as a rule shows no abnormality, though lumbar puncture may be difficult or impossible at the usual level, owing to the spinal canal being filled with fat. Radiography shows defective fusion of the laminal arches in the affected region. Lipiodol after cisternal injection may be arrested at an abnormally high level and it may be possible by this method to demonstrate the constricting band described by Léri.

Diagnosis.

The diagnosis of severe forms of spina bifida with a protruding sac is easy. Spina bifida occulta, however, is repeatedly missed, chiefly because it is not borne in mind as a possible cause of the symptoms

of which the patient complains. All cases of enuresis for which no cause can be found, especially when precipitate micturition occurs by day, should be carefully investigated for the minor symptoms of spina bifida in the lower limbs, and radiograms of the lumbo-sacral spine should be taken. The more severe symptoms of spina bifida require to be differentiated from those of a tumour of the cauda equina, while, when trophic lesions are prominent, it is necessary to exclude Raynaud's disease and thrombo-angeitis obliterans. The fact that in spina bifida symptoms have usually been present since birth is an important diagnostic point, and the rarity of pain and *non-progressive character of the symptoms will help to exclude* a tumour. The paroxysms of ischaemia characteristic of Raynaud's disease are absent in spina bifida and the arterial pulse is not reduced in volume, as is the case in thrombo-angeitis obliterans. X-ray examination of the spine affords confirmatory evidence.

Prognosis.

Sufferers from the more severe degrees of spina bifida do not long survive In the case of spina bifida occulta, although no improvement can be expected in the condition of the spinal cord and vertebral column, considerable functional improvement may follow appropriate treatment, especially in childhood. In selected cases benefit may follow operation. Spina bifida occulta does not usually shorten life, though occasionally death may occur as a result of infection of the urinary tract or septicaemia following severe trophic lesions.

Treatment.

Considerable improvement may be expected from appropriate medical treatment of the various symptoms. Massage, electrical treatment, passive movements, and exercises may improve power in the lower limbs. Tenotomy may be required to correct deformities of the feet. Enuresis will frequently respond to belladonna, which should be given in full doses of the tincture or in doses of half a grain of the dry extract as a pill. Retention of urine will necessitate catheterization. Trophic lesions should be treated by rest and appropriate local treatment. Operative interference should be considered when disabling symptoms are present, especially in adult life. *In such cases benefit has been derived from the division of a constricting band,* as described by Léri. Little can be accomplished surgically when the cauda equina is embedded in a pad of fat, but even in such cases some benefit may follow the relief of pressure by laminectomy. There is evidence that absorption of cerebro-spinal fluid may occur in the sac of a meningocele and excision of the sac may intensify an associated *hydrocephalus.*

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II. MYELITIS

Definition: Inflammation of the spinal cord, usually involving both the grey and the white matter, in a considerable part of its transverse extent. When the lesion is limited longitudinally to a few segments, it is described as transverse myelitis; when it spreads progressively upwards, as ascending myelitis.

Aetiology.

The commonest cause of myelitis is syphilis (see pp. 396–7). Less frequently myelitis may be due to participation of the cord in acute or subacute encephalo-myelitis, for example, acute disseminated encephalo-myelitis, disseminated myelitis and optic neuritis, and acute disseminated encephalo-myelitis complicating vaccination, small-pox, measles, chicken-pox, or other specific fevers, and rarely encephalitis lethargica. The virus of herpes zoster may sometimes, by extension, cause a transverse myelitis, as also may the viruses of acute anterior poliomyelitis and lymphocytic choriomeningitis. Myelitis may be the first clinical manifestation of disseminated sclerosis.

Myelitis may be due to infections of the cord with pyogenic organisms, which may reach it through a penetrating wound, by extension from osteomyelitis of an adjacent vertebra, by inward spread from pyogenic meningitis, e.g. meningococcal meningitis, or through the blood-stream from a focus of infection in any part of the body, the latter being the route of infection when myelitis complicates typhoid or abortus fever. Tuberculous myelitis may follow tuberculous caries of the spine. Toxins which rarely cause myelitis include spinal anaesthetics and sulphanilamide.

There remain a few cases of myelitis for which no cause can be found and which probably constitute a form of acute disseminated encephalo-myelitis.

Pathology.

To the naked eye the spinal cord at the site of infection, which is usually the lower dorsal region, exhibits oedema and hyperaemia,

and in severe cases actual softening—myelomalacia. Microscopically the leptomeninges are congested and infiltrated with inflammatory cells. The substance of the cord exhibits congestion or thrombosis of the vessels with perivascular inflammatory infiltration, and oedema. There is degeneration of the ganglion cells of the grey matter, of the myelin sheaths and axis cylinders of the white. The cord is diffusely infiltrated with inflammatory cells and with compound granular corpuscles. There is a hyperplasia of neuroglia. Ascending and descending degeneration can be traced in the long tracts. Abscess of the spinal cord is a very rare form of localized myelitis. The pus is to a variable extent encapsulated and, as it tends to spread longitudinally, the abscess usually assumes a spindle shape. When myelitis is due to pyogenic organisms, these may be demonstrable in films or on culture, and spirochaetes may be present in the syphilitic form, but in myelitis forming part of acute disseminated encephalo-myelitis and in the form which occurs sporadically no infecting organism has yet been demonstrated.

Symptoms.

The onset of symptoms is acute or subacute, and not uncommonly there is some pyrexia. There is usually considerable pain in the back at the level of the lesion. Flaccid paralysis, partial or complete, then develops more or less rapidly, being confined to part of the trunk and the lower limbs when the dorsal region of the cord is the part involved. Sensory loss, which may be complete or incomplete, is present and usually exhibits an upper level corresponding to the segmental site of the lesion. There may be a zone of hyperalgesia intervening between the area of sensory loss and that of normal sensibility, and the spine may be tender in this region. There is an impairment of sphincter control, often amounting to complete paralysis of the bladder and rectum. The tendon reflexes are usually at first diminished or lost, and the abdominal reflexes are lost below the level of the lesion. The plantar reflexes may be absent for a few days after the onset and later become extensor. In the ascending form of myelitis there is a more or less rapid upward progression of the level of paralysis and sensory loss.

The cerebro-spinal fluid usually contains a considerably increased protein content and an excess of cells, which are polymorphonuclear in cases of pyogenic myelitis, but usually exclusively or predominantly mononuclear in other forms. Queckenstedt's test usually indicates an absence of obstruction in the subarachnoid space, except in rare cases when meningeal adhesions develop. The Wassermann reaction is negative, except in syphilitic cases.

Diagnosis.

The rapid onset of the symptoms of a transverse lesion of the spinal cord usually renders the diagnosis easy. Myelitis is distinguished from Landry's paralysis and from acute infective polyneuritis by the presence of extensor plantar reflexes, and of partial or complete sensory loss with a segmental upper level. Haematomyelia develops more rapidly than myelitis; it usually involves the cervical enlargement and causes greater damage to the grey than to the white matter of the cord. Syphilitic myelitis is distinguished by the history of infection and signs of cerebral syphilis, when these are present, and by a positive Wassermann reaction in the blood and cerebro-spinal fluid. When myelitis forms part of an attack of acute disseminated encephalo-myelitis, symptoms of cerebral lesions may be present, and in the cases following vaccination and the specific fevers the causal condition is usually readily discovered from the history. In disseminated myelitis and optic neuritis the diagnosis is clear when the latter precedes the former. Otherwise it must remain in doubt until optic neuritis develops. When myelitis complicates acute anterior poliomyelitis, the patient exhibits in addition the typical atrophic paralysis. In zoster myelitis the diagnosis is established by the characteristic eruption. Though disseminated sclerosis may be suspected as the cause of a transverse lesion of the spinal cord, especially in a young adult, this diagnosis can only be established if there is a history of previous and characteristic lesions of the nervous system, or if signs of this—for example, pallor of the optic disks or nystagmus—are present. Myelitis can be attributed to infection with pyogenic organisms only when a focus of such infection can be found elsewhere in the body.

Prognosis.

The prognosis depends upon the nature of the infection and its severity. Pyogenic myelitis is usually fatal, and so is the ascending form. Any form of myelitis which is sufficiently severe to lead to a complete functional interruption of the cord is a very grave condition owing to the risk of death from urinary or cutaneous infection. In myelitis forming part of one of the various forms of acute disseminated encephalo-myelitis the prognosis is often good, and if the patient survives the acute attack a large degree of functional recovery is the rule. In sporadic cases of myelitis a guarded prognosis should be given in view of the possibility that the cord lesion may be the first symptom of disseminated sclerosis. For the prognosis of syphilitic myelitis see p. 399, and for that of acute disseminated myelitis with optic neuritis see p. 488.

Treatment.

The general treatment of the patient must be carried out on the lines indicated for the treatment of paraplegia; see p. 610. There is little evidence that drugs influence the lesion of the cord, but iodide may promote the absorption of inflammatory exudate. Analgesics, including morphine, will be required when pain is severe. For the treatment of syphilitic myelitis see p 399, and for that of acute disseminated myelitis with optic neuritis see p. 488.

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12. SENILE PARAPLEGIA

Progressive paralysis of the lower limbs is not uncommon in old age. Though the limbs may be extended, they are more often flexed and contractures frequently develop. As Critchley has pointed out, senile paraplegia may be the result of lesions in several situations. The lesion may be cortical, consisting rarely of a primary degeneration of the pyramidal fibres descending from the leg areas, more often of bilateral vascular lesions within the distribution of the anterior cerebral artery. Subcortical vascular lesions involving both pyramidal tracts may be the cause of paraplegia, but in such cases the upper limbs are likely to be affected also, and pseudo-bulbar palsy or extrapyramidal disturbances, such as Parkinsonism, are often present. The paraplegia may be due to softening of the spinal cord, secondary to atheroma of the spinal arteries, one form of myelomalacia. Lhermitte and Lejonne have described a form of paraplegia occurring in old age and due to sclerosis of the muscles of the lower limbs. This progressive 'myosclerosis' or 'senile myopathy' is the result of hyperplasia of the connective tissue of the muscles, which are hard and tender and develop contractures.

The usual treatment of paraplegia must be carried out (see p 610).

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13. LANDRY'S PARALYSIS

Synonym: Acute ascending paralysis.

Definition: A syndrome of unknown but probably varied aetiology, characterized by flaccid paralysis beginning in the lower limbs and spreading upwards to involve the upper limbs and finally the bulbar and respiratory muscles.

Aetiology.

Little more is known about the aetiology of this rare syndrome than when it was first described under the name 'acute ascending paralysis' by Landry in 1859. Eighty per cent. of the persons affected are males, and most cases occur between the ages of 20 and 30, though cases have been reported below the age of 10 and after the age of 60. Undoubtedly a number of different causes can produce this clinical picture. In epidemics of poliomyelitis some cases are of this kind. Acute infective polyneuritis also may be indistinguishable. Landry's paralysis may occur in measles and German measles. In rare cases rabies in man takes the form of acute ascending paralysis, and disseminated sclerosis, as in one case of the writer's, may terminate in this way. The bite of the Rocky Mountains wood tick, Dermacentor andersoni stiles, may cause ascending paralysis, presumably by means of a toxin since the patient recovers when the tick is removed (Gibbes, 1938). In some cases, therefore, the symptoms are due to the invasion of the nervous system by an organism, in others probably to a toxin. In a small number of cases a micrococcus has been isolated from the blood of affected individuals and has produced paralysis after injection into animals.

Pathology.

The pathological changes in the nervous system may be extremely slight. Hyperaemia of the spinal cord is usually visible to the naked eye. Microscopically the most conspicuous changes are degenerative, consisting of chromatolysis of the ganglion cells of the spinal cord, with degeneration of the peripheral nerves, especially of their myelin sheaths. In most cases perivascular infiltration in the spinal cord is inconspicuous, but cases have been described in which these interstitial changes have been prominent and the histological picture has resembled that of acute anterior poliomyelitis.

Symptoms.

The onset may be abrupt, but is more usually gradual, being preceded by malaise and often by sensory symptoms, such as paraes-

thesiae, pains, numbness, and aching in the back and limbs. Some-
times there are symptoms of meningeal irritation. Fever is sometimes
present, but is often absent. The motor symptoms consist of flaccid
paralysis with loss of the tendon reflexes. This usually begins in the
lower limbs, but occasionally starts elsewhere. It spreads upwards
with more or less rapidity, affecting the trunk and intercostal muscles,
the upper limbs, and finally the bulbar muscles and the diaphragm.
In some cases ophthalmoplegia and facial paralysis occur. It has
often been noted that in the limbs the weakness appears more
marked in the proximal than in the distal muscles, so that feeble
movements of the fingers and toes may persist when the limbs are
otherwise paralysed. Similarly the respiratory muscles may be
relatively less affected than those of the limbs. Muscular wasting is
usually absent, though it is occasionally observed and the reaction of
degeneration is present in the wasted muscles. The plantar reflexes
may be lost, but if elicitable are flexor. The sphincters are relatively
little affected and may escape altogether. In some cases, however,
retention of urine may necessitate catheterization. Sensory loss is
usually absent and if present is slight, but there is often tenderness
of the muscles and peripheral nerves on pressure. Cervical rigidity
and Kernig's sign may be present. Enlargement of the spleen has
been observed in a few cases. The cerebro-spinal fluid is usually under
increased pressure, but may be otherwise normal. In a few cases a
pleocytosis has been described, which is usually mononuclear, but
in one of the writer's cases was polymorphonuclear. More frequently
the protein of the fluid is increased, sometimes very greatly so, and
the fluid is yellow or brown and clots spontaneously.

Diagnosis.

In Landry's paralysis the disturbance of function is practically
confined to the lower motor neurones. Since the same is true of some
cases of acute polyneuritis, a distinction between these two conditions
is possibly artificial. Acute transverse myelitis is distinguished by
the fact that the resulting flaccid paralysis is associated with extensor
plantar reflexes and with considerable loss of all forms of sensibility
below the level of the spinal lesion. Landry's paralysis may be a
manifestation of poliomyelitis and this should be suspected when a
case occurs during a poliomyelitis epidemic or when there is a lympho-
cytic pleocytosis in the cerebro-spinal fluid. The form of Landry's
paralysis due to rabies can only be distinguished from other forms
during life if there is a history of possible infection by a rabid animal.
The true nature of the infection may, however, be demonstrated
post mortem either histologically or by the experimental inoculation
of animals.

Prognosis.

The mortality rate is high, for from 50 to 80 per cent. of affected individuals die. Death usually occurs from respiratory paralysis, less often from broncho-pneumonia. In rapidly progressive cases the patient may die on the third day of the illness. More usually in fatal cases death occurs between the seventh and fifteenth days, but may be delayed as long as six weeks. Recovery, when it occurs, is usually complete in about three months, though occasionally a relapse occurs. Rarely there are residual weakness and wasting of certain muscles.

Treatment.

Treatment is necessarily purely symptomatic, and much depends on good nursing. When the respiratory muscles are affected the patient must be placed in the position most favourable to respiration and the weight of the bedclothes taken by a cradle. Frequent changes of posture are desirable. Foot-drop must be combated by placing a sandbag beneath the soles or by the use of light splints. Catheterization will be needed if retention of urine occurs, and the bowels should be kept open by means of mild aperients and enemata. On the assumption that the patient is suffering from an infection or intoxication of the nervous system, daily lumbar puncture *should be carried out. A sedative will probably be required.* Morphine is contra-indicated in the presence of respiratory paralysis. Phenobarbital in 1-grain doses is an efficient and harmless sedative. Aspirin may be used to relieve the pains in the limbs. Atropine is useful to prevent accumulation of bronchial secretion and should be given subcutaneously in conjunction with strychnine. Artificial respiration with the Drinker or Bragg-Paul respirator may be required when the respiratory paralysis becomes severe.

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INTOXICATIONS AND DEFICIENCY DISORDERS

1. ALCOHOL ADDICTION

Aetiology.

ALCOHOL addiction is a symptom of many different mental disorders and every case requires careful psychological investigation It is more common in males than in females, is rare before the age of 20, and most frequently occurs in middle life. A parental incidence of alcoholism is frequently present, and there is a history of alcoholism in one or both parents of 30 per cent. of patients admitted to institutions for inebriates. Alcoholism may be a symptom of loss of self-control associated with the early stages of dementia, due for example to general paralysis or cerebral arteriosclerosis. It may occur in schizophrenia or in the manic-depressive psychosis. In some cases of dipsomania the periodicity of the outbreaks of alcoholism is due to a periodically recurrent depression in an individual with cyclothymia. Alcohol addicts who are not frankly psychotic are usually neurotic and take alcohol as a means of escape from the difficulties of life. Business worries and domestic unhappiness are common secondary causes. The alcohol is usually taken in the form of spirits; and the alcohol addict may also be a drug addict.

Pathology.

The prolonged consumption of alcohol produces degenerative changes in the central nervous system and in the peripheral nerves, which in their general features are similar to the effects of a large variety of other toxic agents. The brain is atrophied and microscopically there is degeneration of the ganglion cells of the cerebral cortex. The large- and medium-sized pyramidal cells frequently exhibit 'central neuritis' or primary cytolytic degeneration (Pearson) Degeneration of the middle layers of the corpus callosum is said to be *characteristic* (Marchiafava, 1933). *There is an increase in the* capillaries and a secondary glial hyperplasia. Haemorrhages are common. In cases of polyneuritis the peripheral nerves exhibit degeneration of their myelin sheaths and sometimes also of the axis cylinders. There is evidence that the neuritis both central and peripheral is not directly due to the alcohol, but is caused in part at least by deficiency of vitamin B 1 (see p. 712). Similarly alcoholic pellagra occurs. Alcoholism is a predisposing cause of 'pachymeningitis haemorrhagica interna' which, at least in the majority of cases, is now recognized to be a subdural haematoma of traumatic origin.

Symptoms.

Acute Alcoholic Intoxication.

The action of alcohol upon the nervous system is paralytic, the highest functions being first affected. The earliest symptoms of intoxication, therefore, are those of altered behaviour, and the social value of alcohol in moderate doses rests upon its power of paralysing those inhibitions which manifest themselves as shyness and of reducing, in the individual who takes it, his capacity for criticizing his own utterances and those of others. In larger doses it produces irregularities in conduct, the nature of which depends upon the temperament of the individual, who may be excited, voluble, combative, depressed, or maudlin. There is impairment of memory, especially for recent events. At the same time co-ordination suffers and articulation becomes impaired; the conjunctivae are congested, the pupils are usually dilated but may be contracted, and there may be some impairment of the pupillary reaction to light; diplopia may occur. In still larger doses alcohol produces unconsciousness, and finally death, through extension of the paralysis to vital centres

The relationship between the alcoholic content of the blood and the state of the nervous system is variable. Bogen's (1932) correlation of the blood content with the condition of the drinker is an approximate one.

Less than 1 mg. per c.c. of blood					.	dry and decent
1–2 mg.	.	.	.	.	.	delighted and devilish
2–3 mg.	.	.	.	.	.	delinquent and disgusting
3–4 mg.	.	.	.	.	.	dizzy and delirious
4–5 mg.	.	.	.	.	.	dazed and dejected
more than 5 mg.		.	.	.	.	dead drunk

Pathological Drunkenness.

In certain individuals, especially those who have suffered from head injury or organic lesions of the brain, a comparatively small dose of alcohol may rapidly produce the symptoms of acute intoxication.

Delirium Tremens.

The precise cause of delirium tremens is still uncertain. It is most frequently seen as the result of a prolonged debauch in the chronic alcoholic, but may be precipitated in such an individual by acute infection, or operation, or an accident. The sudden deprivation of alcohol undoubtedly plays a part in causation in some cases.

The onset may be acute, but there is often a prodromal period

of nervousness, anorexia, and insomnia The characteristic symptoms are tremor and acute confusion, accompanied by hallucinations, which are principally visual. The tremor is coarse and generalized, but is most evident in the face, tongue, and hands. The patient is completely disorientated and experiences visual hallucinations, which usually assume terrifying forms, especially animals Auditory hallucinations may also be present, and cutaneous sensations may be interpreted as insects crawling under the skin The emotional mood is usually one of terror, and the patient may attempt to escape from his surroundings and may attack with violence those around him. *In addition to these nervous disturbances, symptoms of a severe toxaemia are present.* Slight fever is not uncommon, and albuminuria may be present The tongue is furred, the pulse rapid, and cardiac dilatation may occur. Delirium tremens runs an acute course, and in most cases recovery occurs in three or four days. In the small percentage of cases which end fatally, death is due to heart failure from exhaustion, or intercurrent pneumonia

Acute Alcoholic Hallucinosis

This condition occurs in chronic alcoholics, either developing gradually or coming on suddenly after unusual excess. It is characterized by hallucinations which, unlike those in delirium tremens, are predominantly auditory and are often associated with delusions of persecution.

Dipsomania

In true dipsomania the patient has recurrent drinking-bouts, the craving for alcohol suddenly developing after a period of abstinence. This condition is to be distinguished from pseudo-dipsomania, in which a chronic alcoholic exceeds his usual consumption of alcohol.

Korsakow's Psychosis

Korsakow's psychosis, though most frequently the result of chronic alcoholism with polyneuritis, may be due to other causes (see p 896). The characteristic feature of Korsakow's psychosis is a disturbance of attention and memory which leads to the disorientation of the patient in space and time. His memory for recent events is lost, and he fills the gap by confabulation, that is, the invention of a purely imaginary past For example, a patient who has been bedridden for weeks describes with a wealth of detail a walk which he took on the previous day. Many clinical varieties of Korsakow's psychosis have been described, chiefly in terms of variations of the emotional mood which is usually euphoric.

Alcoholic Dementia.

Prolonged addiction to alcohol leads in many cases to progressive mental deterioration. There is nothing distinctive in the nature of the resulting dementia, which is characterized, like other dementias, by impairment of memory and intellectual capacity, emotional instability, moral deterioration, and carelessness with regard to dress and person Delusions may be present, a delusion of marital infidelity being particularly common.

Alcoholic dementia may be associated with dysarthria, tremor, sluggish pupillary reactions to light, and muscular weakness.

The full clinical picture of alcoholic polyneuritis may be present, but even in the absence of this the tendon reflexes are likely to be lost in the lower limbs.

Epilepsy

Epileptic fits are not uncommon in chronic alcoholism and are indistinguishable from the convulsions of idiopathic epilepsy. The convulsions of absinthe drinkers are due to the presence in the drink of the convulsant drug thujone. How other forms of alcohol cause epilepsy is unknown.

Polyneuritis.

The symptoms of polyneuritis which may complicate any form of chronic alcoholism are described on p. 713.

Diagnosis.

The diagnosis of both acute and chronic alcoholic poisoning presents little difficulty if a reliable history is available. The early stages of acute alcoholic intoxication must be distinguished from the effects of acute lesions of the nervous system, especially those following head injury, and a smell of alcohol in the breath is not proof that the symptoms are due to intoxication. The diagnosis of alcoholic coma is described on p. 303. The clinical picture in delirium tremens is highly distinctive, though I have seen it exactly simulated by cerebral thrombosis involving the frontal lobe. The history, however, and a careful examination of the nervous system will settle the matter. Korsakow's psychosis may be associated with focal cerebral lesions as well as with non-alcoholic forms of polyneuritis, and these must be distinguished from alcoholism by the history and clinical features. Alcoholic dementia must be distinguished from general paralysis. A history of alcoholic excess does not necessarily mean that this is the cause of the dementia, as alcoholism may complicate general paralysis. In doubtful cases the cerebro-spinal fluid and

the blood Wassermann reaction should be examined. In general paralysis characteristic abnormalities are present in the fluid, and the Wassermann reaction both in this and in the blood is positive. In arteriosclerotic dementia general arteriosclerosis is usually conspicuous, and there are frequently a history and signs of focal cerebral vascular lesions.

Prognosis.

The prognosis of alcohol addiction depends upon the underlying cause and the stage at which treatment is begun. When the habit is the expression of a psychotic or a seriously unbalanced personality, or when there is a strong hereditary tendency to alcoholism, the outlook is bad. A history of previous 'cures' and relapses also makes the outlook unsatisfactory. The mortality rate of Korsakow's psychosis is from 30 to 50 per cent. In mild cases recovery may be complete. In more severe cases and cases of long standing there is likely to be some permanent mental enfeeblement.

Alcoholic dementia runs a slow course in most cases, lasting for years. In the early stages withdrawal of alcohol leads to marked improvement, sometimes to complete recovery. In long-standing cases the brain has been permanently damaged and recovery is incomplete. Exceptionally the course is much more rapid, and in a few weeks or months a rapidly progressive dementia terminates in coma and death, often preceded by a terminal hyperpyrexia.

Treatment.

Acute Alcoholic Intoxication.

The stomach should be washed out and a pint of strong coffee should be given by the stomach tube. If the patient is much collapsed, 2 grains of caffeine-sodio-salicylate and 1/30th grain of strychnine sulphate should be given subcutaneously and may be repeated as necessary.

Alcohol Addiction.

The successful treatment of alcohol addiction requires thorough supervision, so that the amount of alcohol taken can be completely controlled. If the patient is to be treated in his own home, reliable nurses will be required. Often treatment can only be carried out successfully in a nursing home or institution. Complete and permanent abstinence from alcohol is the aim, but alcohol should never be suddenly withdrawn. The daily dose should be tapered, and in most cases the withdrawal can be accomplished within a week. Delirium tremens or other acute confusional states may

follow sudden withdrawal. The patient is given the following mixture:

R. Tinct. cmchonae . . . . . . ♏. xx
    Inf. gentian. co. conc. . . . . ♏. x
    Liquor. strychninae nitrat. (gr. iv ad 1 oz.) . . ♏. j
    Glycerin. . . . . . . ♏. xx
    Aq. ad ½ oz., three times a day, in water.

and subcutaneous injections of strychnine and atropine also thrice daily after meals For the injections the following solutions are employed

    Strychnine nitrate . . . gr. iv ad 1 oz.
    Atropine sulphate . . . gr. j ad 1 oz.

beginning with 2 minims of the former and 1 minim of the latter. The dose is slowly increased until 5 minims of the former and 4 minims of the latter have been reached and then gradually reduced. These injections are given for six weeks. Sedative drugs may be required in addition, and it will usually be necessary to give a dose of bromide and chloral at night to ensure sleep. During the period of treatment a careful psychological investigation must be carried out to ascertain the presence of any underlying psychosis or neurosis, and in suitable cases the patient should receive psychotherapeutic treatment. The necessity for complete and permanent abstinence must be impressed upon the patient, as the slightest lapse in this respect may be followed by a relapse into the habit.

Delirium Tremens.

The sufferer from delirium tremens should be treated as a patient with a severe toxaemia involving not only the nervous but also the cardiovascular system. Every effort must be made therefore to keep him in bed, and an adequate supply of experienced mental nurses is indispensable. It is unnecessary to give alcohol, but the patient's strength must be maintained by a light and nourishing diet given at frequent intervals, a brisk purge being given at the onset of the attack Full doses of sedatives will be required; if the patient will swallow he should be given potassium bromide, gr. xx, and phenobarbital, gr j, every four hours until the delirium begins to abate, or the attack may be cut short by an intravenous injection of 3 c.c. of a 10 per cent. solution of sodium evipan or 2 c.c. of pernocton. Heart failure may be combated by digitalis by the mouth, by strophanthin intravenously, or by a subcutaneous injection of camphor or coramine. In severe cases lumbar puncture at an early stage may diminish the excitement.

Acute Alcoholic Hallucinosis.

Hallucinosis should be treated on the same lines as delirium tremens.

Dipsomania.

The sufferer from dipsomania should be urged to report to his doctor as soon as he experiences the slightest return of the craving. If he can be persuaded to do this he should be treated in bed with small injections of apomorphine, 1/40th to 1/20th of a gram being given twice or three times daily. The dose should be large enough to cause slight nausea, but it is unnecessary to cause vomiting. This treatment will check the craving and should be continued until all desire for alcohol has passed away. If the patient is not seen until he is in the middle of the drinking-bout, a larger dose of apomorphine should be given in order to induce vomiting. One-twelfth of a gram is usually sufficient for this. In addition to causing vomiting this has a markedly sedative effect. The patient is subsequently treated with smaller doses by the method described for aborting an attack. A sedative should be given at night.

Alcoholic dementia and *Korsakow's psychosis* must be treated by the methods described for alcohol addiction and polyneuritis.

The treatment of *alcoholic polyneuritis* is described on p. 715.

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2. DRUG ADDICTION

General Considerations.

Drug addiction may be defined as the habitual use of a drug in order to modify the personality and to diminish the strain of life. It is usually characterized by tolerance, craving, and the development

of severe symptoms on deprivation of the drug. Drugs of addiction include opium and its derivatives, morphine, heroin, eucodal, and dilaudid; cocaine, Indian hemp, mescal, the barbiturates, bromides, chloral, alcohol, and allied substances such as ether and paraldehyde; benzedrine and thyroid extract.

Certain groups of these drugs possess distinctive features.

(1) The opium derivatives evoke a high degree of tolerance which is associated with severe deprivation symptoms and the specific toxic effects of the drug upon the addict are relatively slight.

(2) Cocaine gives rise to little or no tolerance and deprivation symptoms are slight or absent.

(3) The synthetic hypnotics and bromides tend to produce their usual toxic effects in the addict.

(4) The picture of alcohol addiction also is often complicated by toxic symptoms, and its ready availability renders the psychological aspect of alcohol addiction exceptionally complex.

MORPHINE AND HEROIN ADDICTION

Aetiology.

The morphine and heroin addict often acquires his habit as a result of the legitimate administration of the drug for the relief of physical pain. As tolerance develops, increasing doses are required for this purpose. After a time he finds that he is unable to relinquish the drug without developing the symptoms of deprivation described below. Moreover, to avoid this, he requires increasing doses, so that he may need 10 grains, or even more, a day. Morphine gives the addict no pleasurable sensations. As De Quincey wrote: 'Opium had long ceased to found its empire upon spells of pleasure; it was solely by the tortures connected with the attempt to abjure it that it kept its hold.' Very few, however, who receive narcotics for the relief of pain become addicts. The drug, besides relieving pain, blunts the edge of reality. To the psychologically unstable therefore it affords a way of escape from life's difficulties. Having experienced the sedative effects of morphine, they continue to take it for the relief of mental pain or distress and are thus fettered to their habit by a double bond, psychological and physiological. Adams classifies addicts in four groups:

1 Stabilized addicts who may lead useful lives on a fixed dose.
2 Accidental addicts, not necessarily psychopathic, who have often acquired addiction through treatment of a painful disease.
3. Natural addicts, essentially psychopathic.
4. Criminal addicts, who take to drugs for vicious purposes.

Doctors and nurses form a considerable proportion of addicts, since they have ready access to the drugs. Residence in a country where

they are readily obtainable may also facilitate the acquisition of the habit. The number of drug addicts in the United States is said to be 100,000, in Canada 8,000, and in Great Britain 700

Symptoms of Addiction.

The addict undergoes a progressive mental deterioration, with loss of interest in his environment, of intellectual efficiency, and of self-respect. He becomes quite untrustworthy, and will commit almost any crime to obtain a supply of his drug if he is faced by the prospect of deprivation. Physically he presents a picture of chronic toxaemia, including the specific symptoms attributable to the pharmacological action of the drug. He is wasted and shows trophic changes in the hair and nails. The pupils are usually contracted and react sluggishly to light. The alimentary tract suffers severely; the appetite is poor and constipation is always present. There is severe fatiguability and muscular weakness, with frequently some ataxia. The pulse is of small volume, and the extremities are cold. Slight albuminuria may be present. Carelessness leads to infection of the skin at the site of the injections, and the resulting scars are usually to be found, while in some cases abscesses or ulcers may be present when the patient comes under observation.

Symptoms of Deprivation.

The addict who is suddenly deprived of his drug exhibits a highly characteristic train of symptoms. As the time for his usual injection passes he becomes restless and apprehensive, and yawning and sneezing develop, being followed by the symptoms of an acute coryza. He feels cold and contraction of the smooth muscles of the skin produces the appearance described as 'goose-flesh'. Later he complains of cramps in the abdomen, back, or lower limbs. His face is contracted in his distress, perspiration is excessive and muscular spasms and twitching occur, most violently in the lower extremities. There is often a general tremor and the patient may be violent in his demands for the drug. Later vomiting and diarrhoea occur and lead to a stage of complete collapse, which may even terminate in death.

Many explanations of the symptoms of deprivation have been proposed. The most plausible is a modification of Dixon's 'release' theory. Since morphine depresses many autonomic functions tolerance must involve the balancing of increasing doses by a progressively higher 'gearing' of autonomic functions. When the morphine is suddenly withdrawn the autonomic nervous system 'races' like a motor-car engine when the clutch is suddenly thrown out. Nevertheless, psychological factors must also play a part since it is said

that in prisons, where abrupt withdrawal without medication is the rule, severe abstinence symptoms are rarely seen.

Treatment.

Not every drug addict requires treatment. Stabilized addicts leading useful lives on a fixed dose, especially when past middle age, are often best left untreated.

Two alternative methods of treatment are in common use—gradual tapering and sudden withdrawal of the drug. In both cases the essential feature of the treatment is to cover the symptoms of withdrawal by the administration of large doses of drugs of the belladonna group. The gradual method has much to commend it in that it can be accomplished with very little discomfort to the patient, and patients thus treated appear to be less liable to relapse. Whichever method is pursued the patient must be completely isolated, preferably in a nursing home, and the assistance of nurses experienced in dealing with this type of case will be required. Care must be taken to see that he has no access to supplies of the drug during his treatment, and it is important to know accurately the amount he has been taking.

If the gradual method is to be used, the patient is given the following mixture (Scott's modification of Lambert's mixture):

R.	Tinct. belladonnae	.	.	.	.	2 parts
	Ext. hyoscyami liq.	.	.	.	.	1 part
	Water	.	.	.	.	.	1 part

At first 5 minims of this mixture are administered in a capsule every hour during the day, and the dose is increased daily, at first gradually and then more rapidly, until symptoms of belladonna intoxication make their appearance. The addict is often extremely tolerant of belladonna and may be able to take one drachm of the mixture hourly without any symptoms appearing. It is not essential that belladonna intoxication should occur. On the first day the accustomed dose of morphine is administered at the usual time. This may be halved on the second day and is subsequently gradually reduced as the condition of the patient permits. Towards the end of the withdrawal saline injections are substituted for some of the daily doses. If slight symptoms of depression occur a small supplementary dose should be given. Phenobarbital in large doses, gr. iii–v, is given at night, and during the last few days of withdrawal additional doses of phenobarbital may be needed during the day.

Drastic purgation is not required, but doses of purgative adequate to ensure a daily evacuation of the bowels should be given. Withdrawal of the drug should be complete in about ten days. The

mixture is stopped on the following day, and the nightly doses of phenobarbital gradually reduced.

If the method of sudden withdrawal is to be used, the patient is given his usual dose of morphine for the first twenty-four hours and during this period he also receives a purgative dose of calomel, followed after eight hours by a saline aperient. At the end of twenty-four hours the morphine is stopped and treatment with hyoscine hydrobromide is begun. The patient receives hypodermic injections *of this drug at four-hourly intervals, as follows: three doses of 1/200th* grain; three doses of 1/150th grain, and three doses of 1/100th grain, each dose accompanied by 1/40th of a grain of strychnine. Two hours after the last injection of hyoscine 1/8th grain of pilocarpine nitrate is injected, and this dose is repeated four times at hourly intervals. The period of the hyoscine treatment lasts for thirty-six hours, and if, when its effects disappear, there are still symptoms of morphine deprivation, large doses of phenobarbital are given, or a single dose of ¼ grain of morphine sulphate. The patient will require sedatives for three or four days, the total period covered by the treatment being about ten days.

Other substances which are used to cover the withdrawal are insulin and diphenylmethylpyrazolonyl (Rossum). Autoserotherapy with blister fluid (Modino's method) or whole blood has also been employed.

The after-treatment of the morphine addict is important, if a relapse is to be prevented. Convalescence under medical supervision should last for three months. Any painful condition which has necessitated morphine in the past should as far as possible be remedied. Psychotherapy may be required to combat an underlying neurosis. It is desirable that the patient should abstain from alcohol, which predisposes to a relapse.

COCAINE ADDICTION

Coca leaves are chewed in South America for their sedative effects and their power of abolishing fatigue. Cocaine as a drug of addiction may be injected subcutaneously, drunk as coca wine, smoked, or taken as snuff. It acts to some extent as a sexual stimulant and is stated to produce a sense of internal peace. Addicts suffer from *mental deterioration, and, in severe cases, from confusional insanity.* Hallucinations, especially of insects crawling under the skin, are common, and epilepsy may occur. Cocaine sniffing may lead to ulceration of the nasal septum. Addicts who are suddenly deprived of cocaine do not suffer, like morphine addicts, from severe deprivation symptoms. Treatment, therefore, *is not required to counteract* these, but is similar to the after-treatment of the morphine addict.

Cocainism, however, is much more difficult to cure than morphine addiction.

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THE SYNTHETIC HYPNOTICS

Barbital, sodium barbital, phenobarbital, chloral, sulphonal, and allied drugs may be taken as drugs of addiction, either alone or with morphine, and addicts become tolerant of enormous doses. All these drugs produce similar symptoms, both in cases of acute poisoning and in addicts, though some have in addition individual peculiarities.

Acute Poisoning.

Poisoning with barbital and its derivatives may occur as a result of an accidental overdose, or the drug may be taken with suicidal intent. Large doses rapidly produce coma; the pupils are usually moderately dilated and may fail to react. The extremities are cold and cyanosed. Respiration is rapid and shallow, and the pulse is rapid and feeble. The plantar reflexes may be extensor, as in deep coma from any cause. The tendon reflexes are usually diminished or lost. In slighter cases of poisoning the patient is mentally confused when roused; speech is dysarthric; the limbs are tremulous and the gait is ataxic.

The stomach should be washed out, and a pint of strong coffee should be given by the stomach tube. The cerebro-spinal fluid should be well drained by lumbar puncture. Large doses of strychnine, at least 1/6th grain an hour, are given; the patient being carefully watched for strychnine poisoning, until consciousness returns. Respiratory and cardiac failure is treated with coramine, 5 c.c. being given intravenously and repeated as necessary.

Addiction to the Synthetic Hypnotics.

When taken habitually these drugs lead to mental deterioration, dysarthria, nystagmus, muscular weakness, tremor, and inco-ordination. There is usually considerable emaciation. Veronal and sulphonal may lead to haematoporphyrinuria and polyneuritis. Chloral has a markedly toxic effect on the heart and on the skin, causing reddening of the face and a papular eruption. Treatment is carried out on the same lines as for morphine addiction.

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CHRONIC BROMIDE INTOXICATION

Chronic bromide intoxication may occur as a result of addiction, which is rare, or in consequence of the prolonged administration of bromide for therapeutic purposes. It is therefore most often encountered in patients who are suffering from neurosis, hyperthyroidism, or epilepsy.

Bromide tends to replace the chlorides in the body and a greater amount of bromide will be absorbed by a person with a low chloride intake than by one who is taking larger amounts of chloride. The blood bromide level is a rough index of the degree of intoxication, though individual susceptibility varies greatly. The normal level of bromide in the blood is under 3 mg. per cent. According to Barbour, Pilkington, and Sargant (1936), levels of under 100 mg. per cent. can usually be ignored, those between 100 and 200 mg. per cent. are likely to be associated with symptoms of intoxication in elderly patients or in those with impaired cardiovascular or renal deficiency, and levels of over 200 mg. per cent produce symptoms in most cases. There is evidence that bromide, like chloride, is excreted into the stomach and so may be reabsorbed.

In mild cases the symptoms are largely subjective and consist of depression, fatiguability, inability to concentrate, loss of memory, lack of appetite, and poor sleep. In more severe cases the mental state is usually one of confusion with some disorientation. The occurrence of terrifying hallucinations, especially at night, is rather characteristic. Physical symptoms are variable: when severe they consist of slurred speech, tremor and ataxia of the upper limbs, a staggering gait, and diminution or loss of the tendon reflexes. In more severe cases still the patient becomes stuporose. The rash usually regarded as characteristic of bromide intoxication is frequently absent.

The bromide must be immediately discontinued and the patient given increased sodium chloride by the mouth or, in severe cases, intravenously. Restlessness is controlled if necessary by paraldehyde or by small doses of a barbiturate.

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3. LEAD POISONING

Aetiology.

The nervous symptoms of plumbism are usually due to chronic poisoning with lead. Industrial lead poisoning was at one time common, but has now been reduced by legislative restrictions. Lead poisoning still occurs, however, especially among plumbers and painters. In such cases the principal route of absorption of the lead is probably by the digestive tract, though some may enter the body through the lungs. Water which has passed through lead pipes is an occasional source of poisoning, and beer and cider may be similarly contaminated. The first glass of these beverages, which has stayed in a lead pipe all night, is particularly poisonous. In children sucking lead paint is the commonest cause of poisoning. Cosmetics containing lead are an occasional source of poisoning, which may also follow the use of lead obtained from diachylon plaster as a home-made abortifacient. Lead tetra-ethyl is a highly poisonous substance which has caused encephalopathy in the United States. It is used in small quantities in some forms of petrol. In chronic lead poisoning, as Aub and his fellow workers have shown, 95 per cent. of the lead is stored in the bones as insoluble phosphate. This lead storage is facilitated by a diet rich in calcium. In states of acidosis the stored lead is released into the blood-stream, and its excretion in the faeces and urine is much increased. Hunter and Aub (1926-7) have shown that mobilization and excretion of lead can be similarly effected by parathyroid extract (parathormone). The undue mobilization of lead may precipitate an attack of encephalopathy. The researches of Aub have thrown new light upon the nature of so-called 'neuritis'. It has long been known that in this condition the muscles paralysed are usually those most used in the patient's occupation. Reznikoff and Aub (1927) have experimentally produced selective muscular paralysis in animals with lead poisoning by fatiguing certain muscles. They believe that lactic acid liberated in the muscles by their contractions leads to the focal formation of lead acetate from the lead phosphate in the blood, and that from the lead acetate insoluble lead phosphate is precipitated in the muscle-cells. This form of lead palsy is thus explained as due not to neuritis but to a local poisoning by lead of the muscles which are used most, a view put forward by Todd in 1834.

Pathology.

There is much experimental evidence that lead poisoning produces a selective degeneration of the ganglion cells of the nervous system, and this is most marked in the spinal cord. Mott has described

similar changes in chronic lead poisoning in man. Chronic cerebral symptoms and local and general progressive muscular atrophy in lead poisoning are, therefore, probably due to degeneration of the ganglion cells of the cerebral cortex and of the anterior horns of the spinal cord respectively. Buzzard and Greenfield state that in acute lead encephalopathy the brain is pale and œdematous, with an excess of fluid in the subarachnoid space. They regard the symptoms of lead encephalopathy as due to a spasm of the cerebral arteries, and the clinical picture has much in common with hypertensive encephalopathy, but there is evidence that the ganglion cells may be directly affected and that meningeal irritation may also occur. Reasons have already been given for attributing the symptoms of so-called lead 'neuritis' to intoxication of the muscles. Degenerative changes have been described in the periphery of the nerves innervating such muscles, but they may well be due to ascending degeneration. Experiment suggests that lead has no direct action on the peripheral nerve.

Symptoms.

Acute Encephalopathy.

This is an acute cerebral disturbance characterized by convulsions, delirium, and coma, often associated with papilloedema and sometimes with cervical rigidity. The cerebro-spinal fluid frequently shows abnormality; its pressure is increased and there is an excess of globulin and of cells, which in adults are usually lymphocytes, though in children polymorphonuclear cells may be present. An increase in the sugar content of the fluid has also been described and the presence of lead in it has been demonstrated.

Chronic Encephalopathy.

Mental changes and epileptiform convulsions have been observed as chronic manifestations of lead poisoning. Primary optic atrophy occasionally occurs. Laryngeal palsy is a rare symptom which has been described by Gowers and by Harris, who saw a case of bilateral abductor paralysis.

Lead 'Neuritis'.

This condition, for reasons already given better described as lead myopathy, usually affects the extensor muscles of the wrist and fingers, as a rule bilaterally, though the right side may suffer alone, especially in right-handed individuals. Wrist- and finger-drop occur, and the loss of synergic extension of the wrist causes weakness of flexion of the fingers. The supinator longus muscle escapes and so,

as a rule, does the extensor ossis metacarpi pollicis. In the upper-arm type of palsy the spinati, deltoid, biceps, brachialis anticus, and supinator longus muscles are affected. These are the abductor and external rotators of the shoulder and flexors of the forearm, and this distribution of paralysis may occur in workers employing these muscles chiefly, for example, in men grinding lead in a mortar. The lower limbs are occasionally affected, the muscles paralysed being those supplied by the external popliteal nerve, with the exception of the tibialis anticus, which usually escapes.

The paralysed muscles waste and exhibit the reaction of degenera-tion, but fibrillation and sensory changes are absent.

Progressive Muscular Atrophy.

Progressive muscular atrophy due to lead poisoning may occur in a localized form involving the small muscles of the hand, when it is usually associated with the common paralysis of the extensors of the wrist and fingers. Fibrillation, which is absent from the muscles paralysed in lead 'neuritis', is present in those degenerating through the action of lead on the anterior horn cells of the spinal cord. Rarely progressive muscular atrophy becomes generalized, and cases have been described in which it has been associated with signs of degenera-tion of the pyramidal tracts.

Other Symptoms.

Other symptoms of lead poisoning are of diagnostic importance. The blue line should be sought on the gums. There may be a history of colic. There is often a secondary anaemia, with stippling of the red cells—punctate basophilia. Cardiovascular hypertrophy with high blood-pressure may be present, or the symptoms of chronic nephritis. Gout is a rare complication to-day. In chronic lead poi-soning in children X-rays may show a 'lead line', a band of increased density, at the diaphyseal end of the growing bones.

Diagnosis.

Acute lead encephalopathy must be distinguished from uraemia, in which there is always a high blood-urea content, and from hyper-tensive encephalopathy in which the blood-pressure is usually higher. Meningitis may be simulated. Lead 'neuritis' is distinguished from a lesion of the musculospiral nerve by the escape of the supinator longus and by its gradual onset and bilateral distribution. In the various forms of toxic polyneuritis, foot-drop is usually associated with wrist-drop; pain in the limbs is often a prominent symptom; and there is usually sensory loss with a 'glove and stocking' distribu-

tion. Moreover, the blue line on the gums and other symptoms of lead poisoning are absent. The progressive muscular atrophy due to lead can only be distinguished from other forms of progressive muscular atrophy by the discovery of other symptoms of lead poisoning. In all doubtful cases lead should be sought in the urine and faeces.

Prognosis.

The outlook in acute encephalopathy is always serious, especially when convulsions occur, but with modern methods of treatment the prognosis has improved and recovery, when it occurs, is usually complete. Little improvement is to be expected in chronic encephalopathy. In lead 'neuritis' the prognosis is good, provided the patient abstains from contact with lead. Recovery, however, is usually slow and may take one to two years. In progressive muscular atrophy due to lead no improvement is likely to occur but the condition may become arrested.

Treatment.

In all cases of lead poisoning the patient must not only be removed from contact with lead, but must never return to an occupation which exposes him to it. If he does so, relapse is certain. The modern treatment of lead poisoning is based upon the physiological investigations of Aub and his colleagues, and has been reviewed by Hunter (1930). Since encephalopathy and palsy are probably secondary to the mobilization of lead in the blood-stream, a diet rich in calcium should be given at first, to favour storage of lead in the bones The patient should take large quantities of milk, and in addition calcium lactate may be given in doses of 40 grains three times a day In encephalopathy cerebro-spinal drainage should be carried out by lumbar puncture, repeated twice a day as long as necessary. Twenty-five to 100 c.c. of 50 per cent. solution of sucrose may be given intravenously, or 2 to 8 oz. of 25 per cent. of magnesium sulphate solution per rectum, according to age, to reduce the cerebral oedema. Five to 10 c c. of calcium gluconate solution should be given intramuscularly and vitamin D by the mouth to aid the deposition of lead in the bones. After the acute stage of encephalopathy and when the progress of lead palsy is arrested, treatment is directed to the gradual elimination of lead from the body. A low calcium diet is given containing not more than 100 mg of calcium a day, together with ammonium chloride in 1-gramme doses in a glass of water six or eight times a day. Provided there is no nausea or headache this treatment is continued for two or three weeks. The ammonium chloride by causing acidosis promotes the mobilization and excretion

of lead. If symptoms of intoxication appear, the ammonium chloride must be stopped and a high calcium diet used once more. Parathormone has been similarly used to eliminate the lead, but is unnecessary. Wrist-drop and finger-drop must be treated by a splint by the method described for musculospiral paralysis, and the muscles treated by the methods employed after a peripheral nerve lesion.

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4. ARSENO-BENZENE ENCEPHALOPATHY

Encephalopathy is fortunately a rare complication of treatment with arseno-benzene derivatives. It may occur after the first dose and is probably a manifestation of idiosyncrasy. In fatal cases the brain exhibits oedema and small perivascular haemorrhages and, in addition, non-haemorrhagic perivascular areas of necrosis and demyelination (Russell, 1937). The onset usually occurs from one to two days after the administration of an intravenous dose. Vomiting and headache are rapidly followed by restlessness and delirium, passing into coma. Generalized convulsions frequently occur. In fatal cases death usually occurs in two or three days. Lumbar puncture should be carried out as early as possible, and repeated every few hours. Sodium thiosulphate should be injected intravenously, as described for the treatment of arsenical polyneuritis, and an injection of 10 minims of 1 in 1,000 adrenalin given subcutaneously. Otherwise treatment is symptomatic.

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5. CARBON MONOXIDE POISONING

Aetiology.

Carbon monoxide poisoning may occur as the result of the accidental or suicidal inhalation of coal gas or of gas from a motor-car exhaust. Carbon monoxide may also be present in dangerous quantities in the air of coal-mines, especially after explosions. By combining with the haemoglobin of the blood to form carboxyhaemoglobin, carbon monoxide reduces the capacity of the blood to take up oxygen, and so leads to anoxaemia.

Absorption of the gas is cumulative, so that a concentration of 0·1 per cent will saturate the blood up to 50 per cent   Effort increases absorption.

Pathology.

In fatal cases the blood is cherry-red in colour and coagulates slowly. All the tissues are reddened. There is oedema of the lungs and haemorrhages are found in the pleura and intestinal mucosa. Changes in the nervous system are of special importance and exhibit a predilection for the cerebral cortex and the corpus striatum. It is said that the globus pallidus is most affected in adults and the caudate nucleus and putamen in children. The small vessels are dilated, and small foci of softening with infiltration with compound granular cells and perivascular infiltration with mononuclear cells are found.

Numerous theories have been put forward to explain the changes in the nervous system (see Hsu and Ch'eng, 1938)   Anoxaemia, vascular disturbance and peculiarities of blood-supply probably all play a part.

Symptoms.

McNally states that the severity of the symptoms can be correlated with the degree of saturation of the blood with the gas. When this is less than 10 per cent there are no symptoms. At between 10 and 20 per cent. the patient complains of slight headache and a tight sensation in the forehead, and there is a dilatation of the cutaneous vessels. At between 30 and 50 per cent. there is severe headache, weakness, giddiness, dimness of vision, nausea, vomiting, and collapse   At between 50 and 60 per cent. the patient becomes comatose and may be convulsed. Paralysis of the heart and respiration occurs, with tachycardia, tachypnoea, cyanosis, and, in some cases, glycosuria.

Prognosis.

In mild cases there is usually complete recovery, but in severe cases the patient may remain comatose for days or even for weeks,

and on recovery may exhibit symptoms of permanent damage to the brain, including aphasia, apraxia, choreo-athetoid movements, and Parkinsonism. Polyneuritis may occur.

Treatment.

The patient should at once be moved from exposure to the gas, preferably to the open air, care being taken to protect the body from loss of heat. Inhalations of oxygen should be given and these may with advantage contain 7 per cent. of carbon dioxide to increase the pulmonary ventilation, the object being as rapidly as possible to replace carboxyhaemoglobin by oxyhaemoglobin. If the patient is unconscious artificial respiration should be carried out by administering the mixture of oxygen and carbon dioxide with a Drinker's respirator. Suitable treatment for heart failure may be required. In the later stages treatment is symptomatic.

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6. CAISSON DISEASE

Aetiology and Pathology.

Caisson disease, also known as compressed-air sickness, diver's paralysis, and 'the bends', first made its appearance with the introduction of high-pressure caissons for submarine work. Divers work in caissons which are open at the bottom and in which the air must be

maintained at a high pressure, usually 30 to 35 lb. to the square inch, to balance the pressure of the water, which increases in proportion to the depth. As a result of the increased air-pressure in the caisson, the tissues of those working in it absorb the gases of the air. If such individuals are suddenly transferred to normal atmospheric pressure, these gases, especially the nitrogen, are liberated in the tissues in the form of small bubbles, in a manner exactly comparable to the liberation of bubbles of carbon dioxide in a bottle of soda water when the cork is removed. The nitrogen is especially soluble in the body fats and is thus liberated in large amounts in the nervous system. For this reason also fat men are more liable to caisson disease than those of spare build. The liberation of bubbles of gas causes not only disruption of the nerve-tissue but also interference with its blood-supply *through blockage of small vessels.*

Symptoms.

The first symptom is usually pain situated in the limbs, trunk, and epigastrium, and sometimes associated with vomiting. The pain usually begins in the knees and hips. Headache and vertigo may occur and in severe cases the patient may rapidly become comatose Hemiplegia or paraplegia with sensory loss may occur.

Prognosis.

In severe cases the condition is fatal. In less severe cases recovery usually occurs, sometimes in a few hours, but disability may persist for days, weeks, or months.

Treatment.

Prophylaxis consists in the slow decompression of workers exposed to high pressures. When symptoms have developed immediate re-compression is necessary, the patient being placed in an air lock for this purpose, and restoration to normal pressure must be extremely *slow. Otherwise treatment is symptomatic.*

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7. ELECTRIC SHOCK

Pathology.

The pathological changes produced in the nervous system by electric shock are highly characteristic. They consist of chromato-

lysis of the ganglion cells, wide dilatation of the perivascular spaces, holes or spaces in the brain itself due to fissures, vascular lesions ranging from focal petechial haemorrhages to actual disruption of large vessels, changes in the peripheral nerves such as fragmentation of the axones and sheaths of Schwann, and a peculiar spiral-like appearance of the muscle fibres. These changes may be associated with electrical burns of the skin.

Aetiology.

There has been much discussion as to the precise way in which electric shock injures the nervous system. The heating effect of the current *may sometimes be sufficient to cause severe damage as in* legal electrocution or lightning stroke. The importance of the electrolytic effect of the current and of its mechanical effect has been stressed by some writers, but Pritchard (1934) points out that neither of these agencies could produce the pathological changes observed, and suggests that in the case of lightning stroke electro-static charges on the surface of the body may be responsible for the disruptive changes found in the nervous system.

Changes in the central nervous system are most likely to occur when the current has been applied directly to the skull. The extreme variability of conditions is no doubt responsible for the unpredictability of the results of exposure to electric currents. Eleven thousand *volts may cause only slight injury (Critchley, 1934). On the other* hand forty volts has been known to prove fatal. Death from electric shock, however, is rare, especially considering the risks of exposure in civilized life.

Symptoms.

A severe electric shock causes immediate loss of consciousness from syncope or concussion. If the patient does not lose consciousness there is usually severe pain associated with bizarre sensory disturbances, especially visual hallucinations. A typical immediate sequel of the shock is a transitory flaccid paraplegia with objective sensory disturbance, both disappearing after about twelve hours. Critchley classifies the neurological sequelae of electric shock as follows: (1) Cerebral, (2) spinal, (3) mixed cerebro-spinal affection, (4) peripheral nerve lesions, isolated or multiple, and (5) psychological disorders, hysteria being particularly common. Symptoms of an isolated cerebral lesion are rare, but spinal atrophic paralyses leading to a clinical picture not unlike progressive muscular atrophy are not uncommon. Brachial neuritis may follow a shock to the upper limbs and Critchley describes a permanent polyneuritic syndrome following lightning stroke.

Prognosis.

Generalizations about prognosis are impossible on account of the varied character of the clinical picture.

Treatment.

The first essential is immediate artificial respiration since by this method it may be possible to revive a victim even though the heart has apparently ceased to beat. It is difficult to know how long artificial respiration should be carried on in the absence of any response, but there is some evidence that resuscitation has been effective even after a period of three hours. During artificial respiration the general treatment of shock should be carried out, and the after treatment will depend upon the nature of the sequelae.

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8. TETANUS

Definition: Tetanus is an intoxication of the nervous system with the exotoxin of the tetanus bacillus. *It is characterized by the progressive development of muscular rigidity which is subject to paroxysmal exacerbations.*

Aetiology.

Tetanus is due to infection with the tetanus bacillus, a Grampositive anaerobic organism which bears spores. The spore is oval or rounded, and develops at one end of the bacillus, which then presents the appearance of a drumstick. The tetanus bacillus is *actively motile, its movement being due to flagella. Bauer and Fildes* have shown by immunological methods that a number of types exist, not all of which are toxic.

The tetanus bacillus is widely distributed in the soil and is found in the faeces of many animals, especially horses, and of a small proportion of normal human beings. The disease arises in man through contamination of wounds with the spores of the organism, especially as a result of accidents in which road dust or soil is introduced into the wound. Other, less common, sources of tetanus infection include vaccination, infection of wounds by contaminated

dressings or catgut, and the injection of infected gelatine and drugs. Tetanus neonatorum, due to infection of the stump of the umbilical cord in newly born infants, is now rare, except in some tropical countries

The mere introduction of tetanus spores into a wound is not sufficient to cause the disease. It appears to be necessary that other organisms should also be present. There is frequently a foreign body, such as a splinter. The tetanus bacilli do not spread beyond the wound, but they produce an exotoxin, by which the nervous system is poisoned. Animal experiments have shown that the toxin reaches the nervous system by ascending the axis-cylinders of the peripheral nerves. The work of Teale and Embleton has shown that the posterior root ganglia act as a filter which prevents the toxin entering the spinal cord by the posterior roots. Its portal of entry is thus confined to the anterior roots. Having thus reached the brain-stem and spinal cord, the toxin produces its characteristic effects by disturbing the normal regulation of the reflex arc. Afferent stimuli not only produce an exaggerated effect, but also reciprocal innervation is abolished and both prime movers and antagonists contract. Hence arises the characteristic muscular spasm.

When a small amount of toxin is slowly absorbed it reaches the anterior horn cells by the route already described. In such cases the first symptom is local spasm of the muscles in the neighbourhood of the wound. When a slightly larger amount of toxin is produced it enters the circulation by way of the lymphatics and reaches the nervous system diffusely by ascending all the peripheral motor nerves. The larger the volume of toxin, the more remains unabsorbed by the anterior horn cells and available to poison distant synapses and ultimately the vital centres. There is then no local tetanus; trismus is usually the first symptom and the spasm subsequently rapidly spreads, to involve the arms, trunk, and legs.

Pathology.

Tetanus is essentially a disorder of function of the nervous system and no constant structural changes have been observed, though hyperaemia may occur in the nervous tissues and rupture of fibres and haemorrhages in the muscles.

Symptoms.

Incubation Period.

The incubation period varies, but is usually seven or eight days. In patients who have had a prophylactic inoculation of antitoxin it may extend to several weeks. Exceptionally it is as short as one or two days.

Descending Form.

A prodromal phase of restlessness and irritability has been described. The first motor symptom is usually trismus, which is rapidly followed, or may be preceded, by stiffness of the neck. At this stage the patient is likely to attribute his symptoms to a chill. Within a few hours, however, the spasm extends to other muscles and dysphagia is often an early complaint. Spasm of the facial muscles may lead either to pursing of the lips or to retraction of the angles of the mouth—the risus sardonicus. The eyes may be partly closed through contraction of the orbicularis oculi, or the eyebrows may be elevated by spasm of the frontalis. Examination reveals the presence of rigidity of the musculature of the limbs and trunk. There may be slight opisthotonos. The muscles of the abdominal wall are rigid, and the lower limbs, which are usually affected more than the upper, are fixed in a position of extension. As the disease progresses this persisting general rigidity undergoes paroxysmal exacerbations which are attended by severe cramp-like pains. Opisthotonic spasm usually occurs in these attacks, but in some cases the *spine is bent in other directions*, for example, forwards or laterally. Spasm of the larynx and respiratory muscles leads to dyspnoea, and profuse sweating occurs. These convulsive paroxysms may be excited by external stimuli, for example, by attempting to feed the patient. Between the paroxysms the general muscular rigidity persists. The tendon reflexes are exaggerated, but with the exceptions described below there are no signs of organic lesion of the nervous system. Consciousness is retained to the end.

Death may occur in a convulsive attack from asphyxia, or, when severe spasms recur frequently, from heart failure. The disease may be apyrexial, but some fever is not uncommon and terminal hyperpyrexia may occur, the temperature even continuing to rise after death. In favourable cases the severity and frequency of the spasms gradually diminish, but the general rigidity frequently persists for several weeks, trismus being often the last abnormality to disappear.

Ascending Form.

In this form of tetanus the first symptom is local spasm of the muscles in the neighbourhood of the wound, whence persistent or intermittent spasm spreads to neighbouring muscles and in severe cases to the other limbs, head, and trunk. After recovery from this form of the disease the original local spasm may persist for days or weeks.

Cephalic Tetanus.

Cephalic tetanus is a rare variety of the ascending form and follows wounds of the head, face, and neck. Muscular paralysis is

frequently present, usually involving the facial muscles on one side
and may be associated with facial spasm on the opposite side. Tris-
mus and pharyngeal spasm usually develop. When the wound has
involved the orbit, ptosis, external ophthalmoplegia, and irido-
plegia have been observed on one or both sides. Cephalic tetanus
may remain localized or become generalized. It is usually fatal,
but when recovery occurs facial paralysis and spasm may persist
for weeks.

Splanchnic Tetanus.

This term has been applied to a form of tetanus which follows
abdominal wounds and in which the bulbar and respiratory muscles
are early and severely affected.

Modified Tetanus.

The symptoms of tetanus may be considerably modified by a
previous prophylactic inoculation of antitoxin. The incubation
period in such cases is usually longer than normal. There is a ten-
dency for the spasm to remain localized to the muscles in the neigh-
bourhood of the wound, and often when generalized tetanus ensues
convulsions are absent, and if they occur are likely to be slight.

Diagnosis.

Conditions causing trismus may be confused with tetanus. Tris-
mus is not uncommonly produced by painful lesions in the neighbour-
hood of the jaw. The presence of the causative lesion and the
localized character of the spasm enable these cases to be distinguished
from tetanus. Trismus may also occur in encephalitis, and in some
cases post-vaccinal encephalitis in which trismus was a prominent
symptom was at first regarded as tetanus. Symptoms of organic
lesion of the brain and spinal cord are always present in such cases
and distinguish them from tetanus. The convulsions of strychnine
poisoning superficially resemble those of tetanus, but develop more
rapidly. Moreover, the fact that they follow reflex excitation is
apparent from the beginning, whereas this is a late feature in tetanus.
Strychnine poisoning also differs from tetanus in that muscular
relaxation is complete between the paroxysms, and the upper limbs
are more severely affected. A history of poisoning can usually be
obtained. Hydrophobia may also be confused with tetanus, but in
this condition trismus is absent and dysphagia is the most conspicu-
ous symptom. Further, muscular relaxation occurs between the
paroxysms and there is almost always a history of a bite by a rabid
animal. Tetany is distinguished from tetanus by the fact that the
muscular spasm always begins in the periphery of the limbs and

leads to the characteristic attitude of the hands. Trismus occurs only in the most severe attacks. Hysteria may cause either trismus or generalized rigidity associated with opisthotonos. Hysterical trismus, however, is not associated with rigidity elsewhere, while hysterical opisthotonos usually forms part of a hysterical convulsion which develops suddenly without pre-existing rigidity, is attended by impairment of consciousness, and is frequently associated with other signs of hysteria.

Prognosis.

The prognosis of tetanus unmodified by prophylactic inoculation of antitoxin is always extremely grave, though the outlook has been somewhat improved by treatment with antitoxic serum. In one series of cases the mortality before the introduction of treatment with serum was 79 per cent. and afterwards 57·7 per cent. Corresponding figures for the London Hospital quoted by Fildes are 81·7 per cent. and 71·8 per cent. In general the shorter the incubation period the worse is the prognosis, and few patients with an incubation period of less than six days recover. Cole (1938) stresses the prognostic importance of the interval between the first symptom and the first generalized reflex spasms, which he calls 'the period of onset.' Patients in whom the period of onset is less than forty-eight hours rarely recover, and in fatal cases the duration of life is rarely more than three times the period of onset.

Prophylaxis.

The introduction of prophylactic inoculation with anti-toxin has reduced the incidence of the disease in those exposed to risk, and mitigated its severity in many who have nevertheless developed it. This is shown by the fact that the incidence of tetanus on the Western Front during the late war was 1·47 per thousand of British wounded, whereas during the Franco-Prussian War it was 3·52 per thousand of German wounded. The influence of prophylactic inoculation in prolonging the incubation period is shown by Bruce's figures for cases in the home hospitals during the late war. The incubation period gradually increased from 11·8 days in 1914 to 50 days in 1918–19 in proportion as prophylactic methods became increasingly efficient.

Prophylactic treatment should be instituted in all cases in which wounds are likely to have been contaminated with soil or road dust. The wound should be curetted and treated with an antiseptic and a dose of 500 units of tetanus antitoxin should be given subcutaneously as early as possible and repeated at intervals of a week until 2,000 units have been given.

Treatment.

The patient should be nursed in isolation and kept as quiet as possible. The occurrence of trismus and pharyngeal spasm frequently renders feeding difficult, and it may be necessary to resort to a nasal tube, liquid nourishment being given.

The curative value of antitoxin is limited by the fact that the nervous system is largely impenetrable by immune bodies. Nevertheless, antitoxin can neutralize toxin in process of absorption and so reduce the dose, perhaps to one the tissues can neutralize. A massive dose—Cole uses 200,000 units—should be given intravenously.

To combat the muscular spasms avertin should be used as for basal anaesthesia in doses of 0·1 c.c. per kilo of body weight, and repeated as necessary. To lessen the risk of pneumonia nasal oxygen and atropin should be given. Evipan sodium has also been used. In milder cases bromide chloral, nembutal and rectal paraldehyde are useful. Local treatment of the wound should be deferred until an hour or two after the antitoxin has been given.

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9. BOTULISM

Definition: A form of food poisoning due to intoxication with the exotoxin of the bacillus botulinus derived from infected foodstuffs, especially those preserved in tins, and characterized by extreme weakness and fatiguability of both striated and unstriated muscle.

Aetiology.

The bacillus botulinus is a large, Gram-positive, anaerobic, spore-bearing organism, which is an inhabitant of the soil in certain regions

and may contaminate food. It finds a most congenial environment in food preserved in tins, especially vegetables and fruit, and both bought and home-preserved foodstuffs may be contaminated with it. It produces a powerful exotoxin, to which the toxic effects are due. Tinned food infected with the bacillus may often be detected as tainted. Production of gas in the tin may abolish the normal vacuum, and the food often has a peculiar rancid odour and taste. This, however, may be disguised by sauces and dressings. There are many examples of severe and fatal poisoning occurring in a person who had only tasted the food to see if it was tainted. Cooking at boiling temperature for a few minutes destroys the toxin. There have been outbreaks of botulism in many countries, especially in Germany, where it was first attributed to eating infected sausages—hence the name, derived from 'botulus', a sausage—and in the United States. An outbreak leading to a number of deaths occurred at Loch Maree in Scotland in 1922. Botulism has frequently been observed in domestic animals which have eaten the remains of tainted food, and fowls which have been thus intoxicated may die before *symptoms appear in human beings who have eaten the same food.*

The investigations of Dickson and Shevky have shown that the muscular weakness is due to a peripheral action of the toxin of botulism, which has a paralytic effect upon the nerve endings in both striated and unstriated muscle.

Pathology.

The changes in the nervous system consist of great congestion of both the brain and meninges, leading to oedema and perivascular haemorrhages.

Symptoms.

In man, symptoms usually develop between eighteen and thirty-six hours after the ingestion of the tainted food, less frequently as early as twelve hours or as late as forty-eight hours or longer afterwards. In about one-third of all cases an acute gastro-intestinal disturbance, characterized by nausea, vomiting, and diarrhoea, occurs, but in most cases this is absent, constipation, probably due *to paresis of the smooth muscle of the intestines, occurring early* and persisting throughout the illness.

The earliest symptoms of muscular weakness are usually visual. Dimness of vision occurs as a result of paresis of accommodation; the pupils become dilated and lose their reaction to light and ptosis usually develops early. Paresis of the external ocular muscles leads to diplopia, and nystagmus may be present. In some cases complete ocular immobility occurs. Vertigo is not uncommon.

Owing to weakness of the muscles concerned, swallowing and talking become difficult; attempts to swallow lead to choking and regurgitation of food through the nose; and there may be complete aphonia. Weakness of the jaw muscles renders mastication difficult or impossible, and the muscles of the trunk and limbs also become extremely weak. The muscular disturbance appears to be an extreme degree of fatiguability, rather than an actual paralysis, since the patient may be able to carry out a movement moderately well on one occasion but be then unable to repeat it. The tendon reflexes are preserved and the plantar reflexes are flexor. There is usually no sensory disturbance. In most cases consciousness remains unimpaired up to the end, though occasionally there is a terminal coma, and terminal convulsions have been described.

The cerebro-spinal fluid is usually normal. The temperature remains normal, unless a complicating infection, such as bronchopneumonia, develops. The pulse is usually rapid. Death occurs either from paralysis of the respiratory muscles or from bronchopneumonia.

Diagnosis.

In cases in which an acute gastro-intestinal disturbance occurs the diagnosis from other forms of acute gastro-enteritis cannot usually be made before the onset of muscular weakness, unless domestic animals have already shown signs of poisoning. The dilated pupils may suggest belladonna poisoning, but the unclouded mental condition enables this to be excluded. Encephalitis lethargica has been confused with botulism, but the onset of symptoms in the former is usually less rapid, lethargy is usually present during the acute stage, and extreme weakness of the muscles innervated by the medulla and of the limbs does not occur. When the diagnosis is doubtful it may be confirmed by the demonstration of the bacillus, botulinus or of its toxins in the remains of food which has been consumed.

Prognosis.

The mortality varies in different outbreaks, ranging between 16 and 65 per cent. Death usually occurs between the fourth and eighth day. Convalescence is very slow in patients who recover.

Treatment.

Prophylaxis consists in the careful scrutiny of all tinned foods and the rejection, without tasting it, of any which appears to be tainted. The cooking of tinned products for ten minutes before use abolishes all risk of botulism. Antitoxin appears to possess greater

prophylactic than curative value, but it can seldom be used before
the onset of muscular symptoms. Twenty thousand units of a
polyvalent serum should be employed. The stomach should be
washed out and a purge administered, this being followed by re-
peated washing of the colon, to remove as far as possible any toxin
which may not have yet been absorbed. Complete rest is of great
importance to protect the muscles from all avoidable fatigue, and
morphine should be given if necessary. Nasal feeding may be re-
quired. Strychnine should be injected subcutaneously in doses of
1/30th grain every four to six hours, and cardiac stimulants may be
needed. In view of the action of the toxin on the nerve endings 2 5
mg. of prostigmine with 1/100 gr of atropine sulphate should be
tried. Oxygen may be necessary if there is severe dyspnoea and is
best administered by means of a Drinker's respirator

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10. ERGOTISM

'Ergotism' is the term applied to poisoning with the toxins pro-
duced by the fungus *claviceps purpurea* of rye Two forms occur, one
characterized by gangrene—the gangrenous form—the other by
nervous phenomena, especially muscular spasms and generalized
convulsions—the convulsive form.

Poisoning with ergot is usually due to the consumption of bread
made from contaminated flour. The gangrenous form is occasionally
produced by the administration of ergot in the attempt to procure
abortion or therapeutically Ergotism is rare in England, but is
commoner on the Continent of Europe, where it was especially
prevalent during the Middle Ages. Epidemics have occurred in
France, Germany, Sweden, Norway, Finland, Russia, and elsewhere,
and in the last-named country ergotism is apparently still endemic.
The gangrenous and the convulsive forms differ in their geographical
distribution, the former occurring to the west, and the latter to

the east, of the Rhine, though mixed epidemics have sometimes been observed where these regions meet. There is reason to believe that the gangrenous form is due to poisoning with ergotoxin or ergotamine, but the convulsive form appears to depend upon the coexistence of two factors, consumption of an unknown constituent of ergot, which is not the alkaloid, together with a deficiency of vitamin A in the diet (Mellanby, Barger).

Convulsive ergotism is associated with degeneration of the spinal cord, especially of the dorsal columns, and also of the peripheral nerves Thickening of the media and hyaline degeneration of the intima of the arteries, sometimes associated with thrombosis, are the changes found in the gangrenous form.

The onset of gangrenous ergotism may be insidious or rapid. Gangrene is usually preceded by severe burning pains, hence the name St. Anthony's fire. Gangrene may involve only the nails, or the fingers or toes or whole limbs, the gangrenous part separating spontaneously without pain or the loss of blood. Convulsive ergotism begins with muscular fibrillation, followed by clonic and tonic muscular spasms, leading to abnormal postures and finally, in severe cases, generalized convulsions. Anaesthesia of the limbs, hemiplegia, and paraplegia may occur.

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11. PELLAGRA

Definition: A disease which appears to be caused by deficiency of an element in the vitamin B2 complex, nicotinic acid. It is characterized by cutaneous lesions, glossitis, diarrhoea, and degeneration of the brain, spinal cord, and peripheral nerves.

Aetiology.

Pellagra is endemic in the poorer strata of the population in many South European countries, in Africa, and especially in the Southern States of U.S.A. It is rare in Great Britain. It may occur at any age, and both sexes are affected with equal frequency. It is commonly but not exclusively found among white maize eaters. Its aetiology was until recently obscure. It has been attributed to a diet deficient in proteins, to the ingestion of toxic substances contained in the

maize and to other hypothetical toxins, but recent evidence appears
to show that it is due to a deficiency of an element in the vitamin B2
complex, nicotinic acid. This is also known as the pellagra-preventing
(P.P.) factor. The administration of nicotinic acid produces imme-
diate improvement in patients suffering from pellagra, and will
prevent the development of pellagra if added to a diet which other-
wise produces it. Endemic pellagra is attributed to a deficiency of
nicotinic acid in the diet. As in the case of other deficiency diseases,
however, defective absorption of nicotinic acid from the alimentary
canal is sometimes the cause of 'secondary' pellagra which may
occur though there is an ample supply of the essential substance in
the diet. 'Secondary' pellagra may thus occur after dysentery or
long continued diarrhoea, after operation or cancer involving the
stomach or small intestine and in alcohol addicts. The disease of
dogs, canine black tongue, like human pellagra, can be prevented or
cured by nicotinic acid.

Pathology.

The meninges are thickened and the brain may be oedematous or
atrophic. Chromatolysis and pigmentation are found in the ganglion
cells throughout the central nervous system and in the autonomic
ganglia. The spinal cord exhibits demyelination of many of the long
tracts. This is most marked in the dorsal columns in the upper
dorsal and cervical regions, but the pyramidal and spino-cerebellar
tracts also suffer. Changes in the peripheral nerves are less conspicu-
ous, and consist mainly of degeneration of the myelin sheaths
Pigmentation and hyaline degeneration have been described in the
cerebral arterioles and capillaries

The principal lesions outside the nervous system are atrophy of
the stomach and intestine, and ulceration is not uncommon in the
large bowel.

Symptoms.

The disease runs a protracted course lasting for many years. The
first attack and subsequent exacerbations tend to occur in the spring.
The early attacks are characterized by gastro-intestinal disturbances,
especially diarrhoea, associated with the development of the cuta-
neous lesions. The latter begin as an erythema involving the parts
of the body exposed to light, while later the deeper layers of the skin
are involved, leading to desquamation, thickening, and finally
atrophy. Exceptionally the cutaneous lesions may be absent. The
tongue exhibits glossitis, with loss of the epithelium, and similar
changes occur in the pharynx. Gastric achylia is the rule and porphy-
rinuria is present. Nervous changes develop later. Many neurotic

and psychotic states occur, depending no doubt partly on the psychological constitution of the patient. Manic and melancholic states may develop, the latter sometimes leading to suicide. Often the terminal state is a dementia. Epileptic fits are not uncommon. Visual impairment and diplopia may occur. Dysarthria and dysphagia may develop in the later stages, together with tremor and ataxia, especially in the lower limbs. The tendon jerks may be increased at first, but later tend to be lost. The plantar reflexes may be extensor. Sensory symptoms consist of pain in the limbs with tenderness of the muscles and superficial anaesthesia and analgesia. There may be loss of appreciation of passive movements of the toes.

Diagnosis.

The clinical picture is unique, and can hardly be confused with anything else, but in the absence of the cutaneous lesions the nervous condition may resemble subacute combined degeneration.

Prognosis.

The prognosis in the past has been bad, most patients after many years ending their days in mental hospitals. Early treatment on modern lines, however, may be expected to bring about a cure in many cases.

Treatment.

Treatment is primarily dietetic. Nicotinic acid should be given. Spies (1938) recommends 0 5 gramme per day given in five doses of 100 milligrammes each for oral administration. If it is necessary to give the substance parenterally 10 to 20 milligrammes may be injected in sterile saline four times a day. Parenteral administration may be necessary where there is reason to think that absorption from the alimentary canal is defective. In the present state of our knowledge it is unwise to rely entirely upon nicotinic acid. Sebrell (1938) advises a high calorie diet 3,000 to 4,000 calories, including at least one quart of milk daily, together with cream and mammalian liver. In addition the diet should include from 30 to 200 grammes of pure dried powdered yeast daily and liver extract should be given parenterally as for subacute combined degeneration. Otherwise treatment is symptomatic.

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12. SUBACUTE COMBINED DEGENERATION OF THE SPINAL CORD

Synonym: Postero-lateral sclerosis.

Definition: A deficiency disease, usually associated with pernicious anaemia and characterized pathologically by degeneration of the white matter of the spinal cord, which is most evident in the posterior and lateral columns, and of the peripheral nerves, and clinically by paraesthesiae, sensory loss, especially impairment of deep sensibility, ataxia, and paraplegia. Subacute combined degeneration was described as progressive pernicious anaemia in tabetic patients by Leichtenstern in 1884, and the spinal cord changes were associated with the anaemia by Lichtheim in 1887. The first complete clinical and pathological account was given by Russell, Batten, and Collier 1900. The therapeutic value of liver was the discovery of Minot and Murphy in 1926 and led to the recognition of extrinsic and intrinsic factors by Castle and his collaborators.

Pathology.

Macroscopical changes in the nervous system are slight. Slight cerebral atrophy has been described and on section of the cord demyelination is evident in the greyish appearance of the white matter. Microscopically two types of lesion are found in the spinal cord, necrotic foci and degeneration of the long tracts. It has been suggested that the latter may be secondary to the former. The necrotic foci, which first appear in the lower cervical and upper thoracic regions of the cord, are irregular patches of demyelination situated in the white matter, near the surface, and are possibly related to the entering blood-vessels. They are most marked in the posterior columns and the pyramidal and ascending cerebellar tracts. Degeneration of the long tracts is most evident in the upper part of the cord in the ascending tracts, and in the lower part in the descending tracts. Both types of lesion are characterized by demyelination, and in the most severely affected regions both the myelin sheaths and the axis cylinders disappear, leaving vacuolated spaces separated by a fine glial meshwork (Fig. 70). Similar focal areas of degeneration have been described in the white matter of the brain,

together with more diffuse degenerative changes in the cerebral association fibres. Degeneration is often present in the peripheral nerves, and the muscles are usually smaller than normal and exhibit a simple atrophy.

In the majority of cases the pathological changes of pernicious anaemia are found in patients dying of subacute combined degeneration. These include glossitis, anaemia, hyperplasia of the red mar-
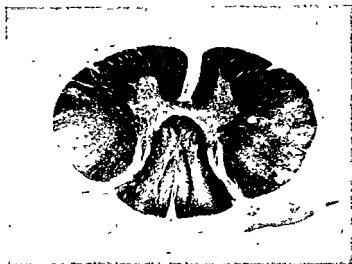
FIG. 70. Subacute combined degeneration. Spinal Cord; Cia.

row in the long bones, slight or moderate enlargement of the spleen, and the presence of iron in the reticulo-endothelial system. Magnus and Ungley (1938) have described in pernicious anaemia a profound atrophy of all coats of the stomach wall localized to the body and sparing the pyloro-duodenal region.

Aetiology.

Subacute combined degeneration is a disease of middle life, the average age of onset being about 50. It may, however, begin as early as 26 or as late as 70. Both sexes are equally affected. Its familial occurrence is rare, but is well authenticated, and families have been described in which multiple cases of subacute combined degeneration and pernicious anaemia have occurred in the same family, sometimes in more than one generation.

The aetiology of the disease is still obscure. In almost all cases subacute combined degeneration is associated with pernicious anaemia, but the relationship between the two disorders is a compli-

cated one. At first it was believed that the degeneration of the spinal cord was secondary to the anaemia, but that this view is incorrect is shown by the fact that the anaemia may be slight or even, exceptionally, absent *when the spinal degeneration is severe*, and *vice versa*. The observation that gastric achlorhydria was almost constantly present in individuals suffering from subacute combined degeneration led Hurst to suggest that the absence of gastric acidity was *the most important causal factor* because the loss of its antibacterial action permitted haemolytic streptococci to pass into the small intestine and there to engender haemolytic and neurolytic toxins.

It is now known, however, that the importance of gastric achylia lies not in the absence of the gastric acidity but in the lack of an intrinsic factor, secreted by the normal stomach, which combines with an extrinsic factor, contained in the food, to form a substance necessary for normal haemopoiesis and for the maintenance of the nutrition of the nervous system. Whether the same substance acts on both the blood-forming organs and the nervous system is uncertain, but if these are two factors they are chemically closely allied. It is unlikely that either vitamin B1 or B2 plays any part in the process. While deficient formation of the essential factor is the usual fault, impaired absorption may cause subacute combined degeneration after gastro-enterostomy. The role of toxins is obscure but an acute infection sometimes precipitates the disorder.

The possibility of an endocrine factor in some cases is suggested by the observation of cases of achlorhydria, anaemia, and subacute combined degeneration associated with pituitary and gonadal insufficiency. (Snapper, Groen, Hunter, and Witts, 1937.)

Although subacute combined degeneration is usually associated with pernicious anaemia, the anaemia may be of the secondary or microcytic variety, while occasionally the blood count is normal. Subacute combined degeneration may also occur in sprue, in patients in a cachectic condition due to malignant disease, and after the operations of partial gastrectomy and gastro-enterostomy. Very rarely it has been described in association with Hodgkin's disease and with leukaemia, but it is difficult in such cases to exclude the possibility that the spinal degeneration may have been due to lymphogranulomatous or leukaemic infiltration of the cord.

Symptoms.

Nervous Symptoms.

The clinical picture is a mixture of posterior column, pyramidal tract and peripheral nerve degeneration.

The onset of symptoms is usually gradual, but is sometimes rapid.

The first symptoms are generally paraesthesiae and consist of tingling sensations, first felt in the tips of the toes and later of the fingers. Less frequently both upper and lower extremities are thus involved simultaneously, or both the hands may be first affected. Other paraesthesiae of which patients complain include sensations of numbness, coldness, and tightness, while pains of a burning or stabbing character, sometimes resembling the lightning pains of tabes, may occur in the limbs and back. The paraesthesiae, which usually begin in the periphery of the lower limbs, tend to spread slowly towards and up the trunk, and a sense of constriction around the chest or abdomen is not uncommon. Motor symptoms consisting of weakness and ataxia develop at a variable interval after the paraesthesiae and begin in the lower limbs. The patient may first notice that he easily becomes tired when walking or that he walks unsteadily and tends to stumble.

Objective sensory changes are constantly present and the forms of sensibility mediated by the posterior columns are always affected. Postural sensibility and appreciation of passive movement and of vibration are impaired first in the lower and later in the upper limbs. Cutaneous sensibility to light touch, pin-prick, heat, and cold is impaired at first over the periphery of the extremities, leading to the characteristic 'glove and stocking' distribution of superficial sensory loss. The calves may be tender on pressure. The proximal border of the anaesthetic areas moves gradually towards the trunk and on the trunk itself moves slowly upwards.

In some cases weakness and spasticity, in others ataxia, predominate in the lower limbs, but both weakness and ataxia are usually present in all four limbs and are more severe in the lower. Inco-ordination in the lower limbs, which is mainly the outcome of defective postural sensibility, is evident in the ataxic gait and in the presence of Romberg's sign. Moderate muscular wasting is usually present in the later stages in the extremities, especially in the peripheral muscles.

The reflexes vary considerably. In more than 50 per cent. of cases the ankle-jerks are absent when the patient comes under observation, the knee-jerks are lost rather less frequently; in other cases both are exaggerated. The plantar reflexes are flexor at first in about 50 per cent. of cases, but later become extensor in all but a small proportion. In a few cases, in which the degeneration is confined to the posterior columns, ataxia is the predominant symptom throughout and signs of pyramidal defect are lacking.

Sphincter disturbances are usually present and consist, in the early stages, of difficult or precipitate micturition, and later of retention of urine or incontinence. Impotence occurs early.

Bilateral primary optic atrophy with some visual impairment is observed in about 5 per cent. of cases, and nystagmus is not uncommon. The pupils may be small, but react normally. Otherwise the cranial nerves are usually normal, though dysarthria may occur.

Mental changes are not uncommon and their importance has recently been stressed by McAlpine. There may be a mild dementia, with impaired memory and intellectual capacity, or a confusional psychosis with disorientation and paranoid tendencies, or Korsakow's psychosis, or the mental disorder may be predominantly affective and manifest itself in irritability or depression with a suicidal tendency. The cerebro-spinal fluid is normal.

Associated Symptoms.

Gastric achlorhydria is constantly present. There is usually anaemia, commonly of the Addisonian or macrocytic variety, characterized by a high colour index—1 to 1·2, or even higher—the presence of normoblasts and megaloblasts, poikilocytosis, anisocytosis, polychromatophilia, and leucopenia, with a relative lymphocytosis. Even when the blood count is apparently normal, it may be possible, by using Price-Jones or some other appropriate technique, to demonstrate the presence of an excessive number of the large red cells characteristic of pernicious anaemia. In a minority of cases the anaemia is of the secondary or microcytic variety, with a low colour index. Subacute combined degeneration and pernicious anaemia are to a large extent independent variables, and it is exceptional for patients who first complain of the nervous symptoms to develop as severe a degree of anaemia as occurs in those who first complain of symptoms of anaemia. Glossitis is common, but appears to be more closely related to the anaemia than to subacute combined degeneration. It may be slight or absent when the anaemia is not severe. Other symptoms may be present if the anaemia is severe. These include dyspnoea, the characteristic lemon tint of the skin, cardiac dilatation, haemic murmurs, and oedema, which is most marked in the lower limbs. The spleen is palpable in only a small proportion of cases. Gastro-intestinal symptoms are common, especially anorexia, flatulence, and diarrhoea. Bodily nutrition is well maintained at first, but general wasting is usually marked in the later stages.

Diagnosis.

When subacute combined degeneration is suspected on neurological grounds a blood count should be made and the gastric acidity investigated. The presence of anaemia and of gastric achlorhydria *affords strong support for the diagnosis, since, apart from their* accidental occurrence, these symptoms are not constantly associated

with any condition with which subacute combined degeneration is likely to be confused. The neurological picture must be distinguished from tabes, disseminated sclerosis, familial ataxia, myelitis, spinal compression, and polyneuritis.

Tabes is distinguished by the absence of extensor plantar responses, except when it happens to be associated with meningo-vascular syphilis. Reflex iridoplegia is usually present in tabes, and in most cases the Wassermann reaction is positive in either the blood or the cerebro-spinal fluid, if not in both.

In disseminated sclerosis there is usually evidence of the disseminated character of the lesions and especially of cerebral involvement, with pallor of the optic disks and nystagmus. The ankle-jerks are usually exaggerated in disseminated sclerosis and very rarely diminished. Difficulty in diagnosis is most likely to arise in the form of disseminated sclerosis characterized by progressive spastic paraplegia which is not uncommon in middle-aged patients. This, however, usually runs a much more chronic course than subacute combined degeneration, and anaemia and gastric achlorhydria are absent.

The familial ataxias may resemble subacute combined degeneration in the association of ataxia of the lower limbs with extensor plantar responses and loss of the knee- and ankle-jerks. This group of disorders, however, is distinguished by the familial incidence, the earlier onset, the presence of nystagmus, and frequently of scoliosis and pes cavus, and the more chronic course.

In myelitis both the posterior and lateral columns are frequently damaged, and the resulting physical signs may therefore resemble those of subacute combined degeneration. The onset of myelitis, however, is acute or subacute, and thereafter the condition remains stationary or tends towards improvement; and when the condition is syphilitic the Wassermann reaction is usually positive, especially in the cerebro-spinal fluid.

Spinal compression may lead to an ataxic paraplegia of gradual onset. Careful investigation of the physical signs, however, indicates a well-defined and unchanging level at the upper limit of the motor disability and sensory loss, and characteristic changes will usually be found in the cerebro-spinal fluid.

Polyneuritis may simulate subacute combined degeneration when paraesthesiae, occurring in the extremities, are associated with ataxia of the lower limbs, loss of the tendon reflexes, and sensory loss of the 'glove and stocking' distribution. It is not surprising that there should be a close resemblance between the two conditions, since it is certain that some of the symptoms of subacute combined degeneration are in fact due to degeneration of the peripheral nerves. In poly-

neuritis, however, there is never any evidence of involvement of the pyramidal tracts. Pains and tenderness of the muscles are more severe as a rule than in subacute combined degeneration, and muscular weakness in the distal segments of the limbs is also more severe.

Prognosis.

The average duration of the illness of pernicious anaemia before the introduction of the modern treatment was about two years. Now it is possible by means of liver extract to restore the blood to normal and maintain the patient in good health indefinitely. Such patients need never develop subacute combined degeneration. When this has already developed it can always be arrested, but the degree of recovery depends upon the stage which the disease has reached The peripheral nerves are capable of regeneration, but this is not possible in the spinal cord, though doubtless here already damaged fibres may be restored to normal. A striking improvement therefore may be expected in the polyneuritic symptoms with disappearance of paraesthesiae and pains in the limbs, sensory loss of the 'glove and stocking' distribution, and muscular wasting, and with return of the tendon reflexes and improvement in co-ordination   Extensor plantar reflexes and spastic weakness and gross loss of postural sensibility, however, usually persist unchanged. Even in patients in whom the disease has been arrested by treatment the development of an infection, especially localized suppuration, may lead to a severe and even fatal exacerbation.

Treatment.

The essential factor which is lacking in subacute combined degeneration may be administered to the patient either (1) by the mouth in the form of raw or lightly cooked liver, liver extract or desiccated hog's stomach or (2) intramuscularly or (3) intravenously in the form of liver extract The intramuscular route is usually the most convenient. The state of the blood is no guide to the dosage required for the nervous symptoms, which is usually much larger than that needed to combat the anaemia.

Unfortunately liver extracts are not at present standardized. A suitable initial dose for a patient with subacute combined degeneration is 20 to 30 c.c. of Campolon in divided doses weekly. This is continued for many weeks until no further improvement occurs. The dose is then reduced till a suitable maintenance dose is found by experience and this must be continued for the rest of the patient's life   Other liver extracts are equally effective including Dakin and West's liver fraction—Anahaemin.

The diet should be ample and well supplied with vitamins. Iron

is of value only if an iron-deficiency anaemia is present. Dilute hydrochloric acid in one drachm doses well diluted with meals may be helpful to relieve dyspeptic symptoms. Massage and re-educational exercises are of great value. Foci of sepsis should receive attention. Analgesics and sedatives may be required at first and in advanced cases the usual care of the skin, bladder, rectum, and paralysed muscles necessitated by paraplegia will be required.

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13. POLYNEURITIS

Synonyms: Multiple symmetrical peripheral neuritis; multiple neuritis; parenchymatous neuritis.

Definition: Polyneuritis is a clinical picture, the essential feature of which is an impairment of function of many peripheral nerves simultaneously, resulting in a symmetrical distribution of flaccid muscular weakness and usually also of sensory disturbances, affecting as a rule the distal more than the proximal segments of the limbs and sometimes also involving the cranial nerves   A simultaneous disorder of the highest cerebral functions, leading to mental disturbances, is common. Polyneuritis thus defined may be caused by

a very large number of agencies, which may operate in several different ways and even at different points of the peripheral nerves. Among such agencies are numerous endogenous and exogenous toxins, acute infections which directly attack the nerves, and vitamin deficiency.

Peripheral neuritis of this kind was recorded by Lettsom in 1789 and an epidemic in Paris was described by Robert Graves in 1828 Todd first conceived that the *terminal branches of the peripheral nerves might undergo degeneration* and this was demonstrated pathologically by Dumenil in 1864 Joffroy in 1879 contributed to the classification of polyneuritis and Grainger Stewart gave it the name multiple symmetrical peripheral neuritis in 1881 Korsakow described the mental changes not uncommonly associated with polyneuritis in 1889

Aetiology.

The causes of polyneuritis are very numerous The following classification includes the most important:

1. EXTERNAL POISONS:

   Metals: Arsenic, antimony, mercury, copper, phosphorus, bismuth, (lead).

   Organic Substances: Carbon monoxide, carbon bisulphide, dinitrobenzol, sulphonal, chloral, chloretone, aniline, tetrachlorethane, triorthocresylphosphate (ginger paralysis and apiol paralysis), sulphanilamide and its compounds, immune sera

2. DEFICIENCY AND METABOLIC DISORDERS:

   Vitamin B 1 deficiency (beri-beri, chronic alcoholism, pregnancy, and chronic diseases of and operations on the gastro-intestinal tract), hunger oedema.

   Pellagra, pernicious anaemia and subacute combined degeneration, sprue.

   Recurrent polyneuritis.

   Diabetes, myxoedema, acromegaly, haematoporphyrinuria.

3. INFECTIVE CONDITIONS:

   (i) *Infections in which polyneuritis is an integral part of the clinical picture:*
   Acute infective, toxic or febrile polyneuritis, 'rheumatic' polyneuritis, parotitis-polyneuritis-iridocyclitis, pink disease.

   (ii) *Polyneuritis complicating acute or chronic infections:*
   Septicaemia, puerperal, typhoid, paratyphoid, scarlet fevers, dysentery, influenza, tuberculosis, syphilis, gonorrhoea, mumps,

typhus, malaria, meningitis, measles, small-pox, focal infection,
periarteritis nodosa.

   (iii) *Infection with organisms whose toxins have an affinity for the
peripheral nerves:*
      Diphtheria, tetanus.

4. LOCAL INFECTION OF NERVES:

    Leprosy.

5. FAMILIAL POLYNEURITIS:

    Progressive hypertrophic polyneuritis of Dejerine and Sottas.

6. POLYNEURITIS OF OBSCURE ORIGIN:

    Chronic progressive polyneuritis.

In some cases the toxin is introduced into the body from without.
In others it is formed within the body as a result of bacterial action
or of metabolic disturbances. Yet again the source may be undis-
coverable. Sometimes the toxin appears to possess a specific affinity
for the peripheral nerves, and it has been suggested that it may
combine with the phospholipins of the medullary sheaths. Such
toxins probably ascend the peripheral nerves. We thus encounter
both a local neuritis involving the nerves supplying the region
in which the toxin originates, for example, palatal paralysis in
diphtheria, and also generalized polyneuritis, in which the toxin is
disseminated in the blood-stream and so reaches the peripheral
nerves throughout the body, subsequently ascending them from
their terminations.

Very varied causes may lead to deficiency of vitamin B 1 which
appears essential to the nutrition of the peripheral nerves. De-
ficiency of other factors may also be important, as in the poly-
neuritis which occurs in subacute combined degeneration, and the
relationship between toxins and vitamin deficiency is largely an
unexplored field.

In other cases the mode of production of polyneuritis is more
obscure.

Pathology.

In general, pathological changes are most marked at, and may be
confined to, the periphery of the nerve-fibres. In other cases the
whole length of the neurone appears to be affected, a condition
which has been described as polyneuronitis. The most conspicuous
alterations are found in the medullary sheaths, the myelin of which
undergoes degeneration, being broken up into globules. There is a
proliferation of the cells of the sheath of Schwann, some of which

assume phagocytic properties. The extent to which the axis cylinders suffer is very variable. In severe cases they undergo severe degeneration. Recovery consists of regeneration of the axis cylinders associated with reformation of the myelin sheaths.

Symptoms and Prognosis.

The symptoms and prognosis of the commoner and more important forms of polyneuritis are described under their respective headings.

Diagnosis.

As a rule the diagnosis of polyneuritis is easy, owing to the characteristic symmetrical and peripheral distribution of the muscular weakness and wasting, pain, tenderness, and sensory impairment. The association of pain, ataxia, and loss of tendon reflexes in the lower limbs may simulate tabes. The pain of polyneuritis, however, which is of a persistent, burning, and tearing character, is quite different from the lightning pains of tabes, and is associated with tenderness of the deep tissues on pressure, whereas in tabes these are insensitive. Although the pupillary reaction to light may be sluggish in polyneuritis, especially in the alcoholic form, a true Argyll Robertson pupil is never found, and the Wassermann reaction is negative, except in patients who happen to suffer both from syphilis and from polyneuritis. As stated elsewhere, some of the symptoms of subacute combined degeneration are due to an associated polyneuritis. The true cause of these symptoms, however, is usually easily established by the presence of extensor plantar responses, impairment of appreciation of vibration over the trunk as well as the limbs, and the presence of anaemia, glossitis, and gastric achylia, *though the last may be present in patients suffering from polyneuritis due to other causes*. When a diagnosis of polyneuritis has been made, the diagnosis of the cause is based upon distinctive features of the history and symptoms peculiar to the different varieties, and described under their respective headings.

Treatment.

The first step in treatment is the removal of the patient from exposure to the causal toxin and its elimination from the body or the correction of abnormal metabolic states or vitamin deficiency. The steps necessary for this are described in the sections dealing with the various forms of polyneuritis. When none of the common toxic causes of the disorder can be discovered, careful search must always be made for sources of infection in the teeth, nasopharynx,

and elsewhere, and the condition of the gastric juice should be investigated by a test meal.

Rest in bed is essential, not only on account of muscular weakness, but also because the heart is frequently involved, either as a result of toxic myocarditis or of neuritis of the vagi. Careful attention should always be paid to the state of the pulse, the position of the cardiac apex, and the state of the apical first sound, and symptoms of cardiac failure should be sought. When the heart is affected, digitalis or cardiac stimulants may be required.

Local treatment consists of the prevention of muscular contractures, the maintenance of the nutrition of the muscles, and the promotion of the recovery of voluntary power. Wrist-drop and foot-drop must be prevented by the use of appropriate splints. As long as muscular tenderness is severe splints cannot be borne, and the feet must then be supported by means of a sandbag placed beneath the soles, the weight of the bedclothes being taken by a cradle. *Later, aluminium night-shoes may be used to support the feet at a right angle.* When contractures have already developed they must be overcome by the use of an extension apparatus, and tenotomy of the tendo Achillis may be required. Daily massage and passive movements should be instituted as soon as the patient is able to bear them, and the muscles may be stimulated electrically. Analgesic drugs will be required when the pain is severe. It is doubtful whether any drug influences the rate of recovery from neuritis, but Harris advocates the subcutaneous injection of strychnine, beginning with a dose of 5 minims of liquor strychninae hydrochlor. twice daily and increasing the daily dose by 1 minim every other day until 9 minims are given twice daily, this dose being continued for several weeks.

Since vitamin B I appears essential to the nutrition of the peripheral nerves it is often given even in cases in which the polyneuritis is not known to be due to deficiency of this vitamin.

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ARSENICAL POLYNEURITIS

Aetiology.

Polyneuritis may follow either acute or chronic arsenical poisoning, more usually the latter. The arsenic may have been administered with intent to murder or in an attempt at suicide. It may have been taken accidentally or medicinally. For murderous purposes

white arsenic or sodium arsenite, which is contained in certain rat-poisons and weed-killers, has usually been employed. Arsenic has also been obtained from fly-papers for this purpose. Accidental arsenical poisoning may occur in occupations involving handling arsenic, though this is rare, or as a result of taking food contaminated with arsenic, as in the Manchester epidemic in 1900, when poisoning was produced by the consumption of beer brewed with glucose containing arsenic. Poisoning has also been produced by the inhalation of arsenic from wall-papers in which it has been used as a dye. Medicinal arsenical poisoning is rare to-day, but was more frequent in the past, when Fowler's solution was administered for long periods in the treatment of chorea and pernicious anaemia. Polyneuritis is rare after treatment with arseno-benzene derivatives.

Pathology.

See p. 706.

Symptoms.

The symptoms of arsenical polyneuritis resemble those of the alcoholic variety. As in the latter, sensory symptoms are conspicuous and pain is usually severe. Muscular weakness is usually more conspicuous in the lower than in the upper limbs. Korsakow's psychosis or a confusional state may be present. In the diagnosis of arsenical polyneuritis the presence of abnormalities outside the nervous system assumes great importance. In chronic arsenical poisoning gastro-intestinal symptoms may be absent. Excessive salivation is not uncommon, and there is often a secondary anaemia. Cutaneous symptoms are usually present. These may consist of erythema or even of exfoliative dermatitis. In long-standing cases there is often cutaneous pigmentation. This is absent from the exposed parts and it consists of a fine mottling of the skin, with patches of a light chocolate colour, the intervening areas being white. Hyperkeratosis of the palms and soles is often found, the thickened skin presenting a smooth, somewhat waxy appearance. White transverse bands composed of deposited arsenic are found in the nails. Herpes zoster is a common complication.

Diagnosis.

The diagnosis of polyneuritis is described on p. 707. The diagnosis of arsenical from other forms of polyneuritis depends upon the presence of the abnormalities just described, especially the cutaneous symptoms of arsenical poisoning, and upon the demonstration by appropriate toxicological tests of arsenic in the hair, nails, urine, or faeces.

Prognosis.

The prognosis of arsenical polyneuritis is good, provided the general symptoms of arsenical poisoning are not too far advanced when the patient comes under treatment. Recovery of voluntary power, however, is slow and may take one or two years.

Treatment.

The patient should be given daily intravenous injections of 0 6 gramme of sodium thiosulphate dissolved in 10 c.c. of sterile distilled water. This forms a harmless compound with the arsenic in the body. In addition the general treatment of polyneuritis should be carried out (see p. 707).

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POLYNEURITIS DUE TO TRIORTHOCRESYLPHOSPHATE

During the spring of 1930, thousands of cases of polyneuritis, some of them fatal, occurred in the United States, owing to the consumption of fluid extract of ginger adulterated with triorthocresylphosphate. The condition became known as 'ginger paralysis'. A recent outbreak of polyneuritis in South Africa has been traced to cresyl esters in cooking-oil. The same toxic substance has been proved responsible for causing polyneuritis in women who have taken apiol as an abortifacient. Both in man and in experimental animals triorthocresylphosphate produces a chromatolysis of the anterior horn cells of the spinal cord and of the ganglion cells of the motor nuclei of the pons and medulla, and destruction of the myelin sheaths and axis cylinders of the peripheral nerves. Symptoms of polyneuritis usually developed from ten to twenty days after the consumption of adulterated ginger, and consisted of bilateral wrist-drop and foot-drop, with wasting of the distal muscles of the limbs. Pain in the limbs was common, but sensory loss was inconstant. In many cases the paralysis has proved to be permanent. Acute retrobulbar neuritis has been described in apiol poisoning. For treatment see p. 707.

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NEURITIS COMPLICATING SEROTHERAPY

Neuritis is a rare sequel of serotherapy. It has been described after the administration of serum in the treatment of tetanus, diphtheria, and scarlet fever. Nervous symptoms usually occur two or three days *after the onset of typical symptoms of serum sickness.* The commonest lesion is a spinal neuritis, the fifth cervical spinal nerve being most commonly affected on one or both sides, with pain in the corresponding segmental distribution and paralysis of the muscles innervated, especially the deltoid. Less frequently the whole brachial plexus may be involved, leading to brachial neuritis, or polyneuritis may occur. Cerebral symptoms, probably resulting from cerebral oedema, rarely occur. Optic neuritis has been described. Complete recovery usually occurs in from one to eighteen months, though occasionally muscular weakness persists. Treatment appropriate to the situation of the lesion must be carried out.

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POLYNEURITIS DUE TO VITAMIN B 1 DEFICIENCY

Aetiology.

Beri-beri was one of the first diseases known to be due to vitamin deficiency, namely lack of vitamin B 1. Recently, deficiency of this *vitamin has been shown to be the main factor in the causation of* polyneuritis associated with chronic alcoholism, pregnancy, various diseases of the alimentary canal, and even restricted diet. It is possible that other causal factors may be operative, but it is convenient to consider all these disorders together in relation to their common factor, deficiency of vitamin B 1.

This vitamin, aneurin, is contained in brewer's yeast, in the germ and aleurone layer of ripe wheat and also in egg yolk, mammalian liver, and in smaller amounts in milk, green vegetables, potatoes, and meat. Adults require at least 550 international units of the vitamin daily. Many modern diets supply only about 350. Since the vitamin is contained in the germinal layer of the ripe grain, natives who live mainly on rice and consume the polished grain are liable to suffer from a deficiency of the vitamin in their diet and hence develop beri-beri. In civilized countries persons who adopt a restricted diet, usually for treatment of some disease of the alimentary canal and continue it for long periods, may similarly develop polyneuritis.

It now seems likely that alcoholic polyneuritis is not due to the toxic effects of the alcohol on the peripheral nerves, but in part at least to a deficiency of vitamin B 1, since if this deficiency is repaired the patient may improve though still permitted to take the alcohol. The main cause of the deficiency appears to be defective absorption due to the effects of the alcohol on the mucous membranes of the alimentary canal and on its enzymes. At the same time the high caloric value of the alcohol increases the need for vitamin B 1, and hence the relative deficiency, and the deficiency itself in turn contributes to the gastric achlorhydria and so sets up a vicious circle. Thus there is no constant relationship between the amount of alcohol consumed and the liability to polyneuritis. Alcoholic polyneuritis is more frequently the result of the consumption of spirits than of other forms of alcoholic drink. The sex and age incidence are those of alcoholic addiction, most patients being middle-aged and males being affected more often than females.

In pregnancy the principal causes of vitamin B 1 deficiency are persistent vomiting, unsuitable diet, and increased requirements due to the needs of the foetus.

Lesions of the alimentary canal may not only interfere with the absorption of the vitamin, but may also lead to the adoption of a deficient diet. Such lesions include pyloric stenosis, gastro-enterostomy, ulcerative colitis, dysentery, and steatorrhoea.

The precise way in which lack of vitamin B 1 causes polyneuritis is unknown. It appears to be essential to the nutrition of the nervous system. Peters and others have stated that in pigeons rendered polyneuritic by lack of vitamin B 1 the brain tissue loses its power to respire and pyruvic acid accumulates in it.

At present it is impossible to be sure that deficiency of other vitamins or dietary factors or even endocrine abnormalities may not play a part in the aetiology of polyneuritis in alcoholism, pregnancy, and disease of the alimentary canal.

Pathology.

The changes in the nervous system are those of degenerative or parenchymatous neuritis (see p 706), which may involve either the *somatic peripheral nerves, or the autonomic nerves, or both*. The whole length of affected neurones exhibits degenerative changes, and chromatolysis is found in the ganglion cells of the anterior horns and posterior root ganglia of the spinal cord, and of the motor nuclei of the cranial nerves The changes in the muscles are those characteristic of degeneration of the lower motor neurones In the wet form of beri-beri there are myocardial degeneration, with enlargement of the right side of the heart, chronic venous congestion of the liver and spleen, effusions in the pleural cavities and pericardium, *ascites*, and oedema of the skin and subcutaneous tissues

Symptoms.

Beri-beri.

The onset in some cases is very rapid In others it is more gradual, and mild or larval forms occur The nervous symptoms are typical of polyneuritis and consist of paraesthesiae and tenderness of the limbs, sensory loss, and progressive atrophic paralysis, with loss of reflexes. Symptoms of cardiac involvement include dyspnoea and palpitations, tachycardia, cardiac dilatation, and symptoms of heart failure. Oedema may be slight or extreme Disturbance of function of the alimentary canal leads to flatulence and constipation or diarrhoea.

Alcoholic Polyneuritis

Sensory disturbances usually play a prominent part in the clinical picture. In the early stages the patient complains of numbness, tingling, and paraesthesiae in the hands and feet, and especially pain in the extremities The pain may be very severe and is described as burning or 'like tearing flesh off the bones'. Cramp-like pains occur in the calves and are especially severe at night. Following the early sensory disturbances the limbs become weak, the lower limbs as a rule being more severely affected than the upper.

As is the rule in polyneuritis, both motor and sensory symptoms affect predominantly the periphery of the limbs and in a symmetrical manner. In severe cases both wrist-drop and foot-drop are present, the latter causing a 'steppage' gait, and there is some wasting of the peripheral muscles of all four limbs. Weakness is most marked in the peripheral segments. If the patient can move his limbs ataxia can usually be demonstrated, and in one form of disorder—the so-called pseudo-tabetic variety—ataxia is conspicuous in the lower limbs and is due to loss of postural sensibility. There is a blunting of all forms

of sensibility in the periphery of the limbs, cutaneous anaesthesia, and analgesia usually extending up to the elbows and knees. Postural sensibility and appreciation of passive movements are impaired in the fingers and toes. At the same time pressure upon the muscles, especially those of the calves, is usually intensely painful, and scratching the sole may also evoke severe pain. Exceptionally pain and tenderness are slight or absent.

The tendon reflexes are diminished or lost, the ankle-jerks disappearing before the knee-jerks. The plantar reflexes may also be lost, but if present are flexor. The skin of the extremities is often oedematous and sweating. Muscular contractures readily develop, especially in the flexors of the fingers, the hamstrings, and the calf muscles, and fibrous adhesions readily occur in the tendon-sheaths and around the joints. The sphincters are usually unaffected.

Abnormalities in the cranial nerves are inconstant. The pupils tend to be contracted and may react sluggishly to light. Nystagmus is common. Neuritis of the cranial nerves may be present, the vagus being most frequently involved, with a resulting tachycardia, and the facial next in frequency. Korsakow's psychosis (see p. 896) or alcoholic dementia may complicate the picture. The cerebro-spinal fluid may be normal, or its protein content may be considerably increased. The symptoms of alcoholic poisoning of other organs besides the nervous system may be present. Gastritis is common and the liver may be enlarged. Myocardial failure may also occur, and pulmonary tuberculosis is a not uncommon complication. Patients are often obese and florid.

The symptoms of polyneuritis complicating pregnancy and lesions of the alimentary canal are similar to those of alcoholic polyneuritis.

Diagnosis.

The diagnosis of polyneuritis in general has been described on p. 707. Deficiency of vitamin B 1 as the cause should be suspected when one of the conditions already enumerated as likely to cause a lack of this vitamin is present. Impaired excretion of the vitamin may be demonstrable in the urine.

Prognosis.

The prognosis of beri-beri is always grave in the wet form, death frequently occurring from sudden heart failure. The outlook is less serious in the dry form, and if cardiac failure does not prove fatal, recovery from the nervous symptoms may be expected, though it is unlikely to be complete for from three to six months. The prognosis of other forms of polyneuritis due to vitamin B 1 deficiency depends upon how early treatment is begun and how far it is possible to

remove or prevent the recurrence of the causal factor. When treatment can be begun early the prognosis is good, but in long-standing cases recovery may be incomplete, especially in respect of return of power to the peripheral muscles. In some cases of alcoholic polyneuritis, in spite of early treatment and the withdrawal of alcohol, the disorder runs a rapidly progressive course with increasing mental confusion, terminating either by death in coma or heart failure or from an intercurrent pneumonia.

Treatment.

Complete rest is essential and the patient must not be allowed to sit up. The primary requirement is adequate dosage with vitamin B 1, which must be given parenterally at first. Strauss (1938) recommends 20 to 50 milligrams of crystalline vitamin B 1 daily at first. Later the dose can be reduced and can be supplemented by the oral administration of 30 grammes of brewer's yeast three times a day, or marmite may be given in doses of half to two ounces daily. The patient should also take a diet rich in vitamin B 1, especially green vegetables, carrots, butter, and mammalian liver, and an adequate supply of vitamin A should be assured. Liver extract may be given. When heart failure is severe venesection may be performed for the relief of the right side of the heart and cardiac stimulants may be necessary. The usual treatment of polyneuritis should be carried out (see p. 707). Other causal factors will require attention. In chronic alcoholics the treatment of alcohol addiction must be combined with that of the polyneuritis (see p. 667). The coincident catarrhal condition of the alimentary canal should receive attention. Patients in whom the vitamin B 1 deficiency is secondary to disease of the stomach, duodenum, or intestine will need appropriate treatment for this.

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DIABETIC POLYNEURITIS

Aetiology.

It is improbable that hyperglycaemia alone is the cause of the neuritis which sometimes complicates diabetes. Age plays a part in

causation, since neuritis is seen almost exclusively in the middle-aged and elderly. It is probable that atheroma of the vasa nervorum is a predisposing factor. The susceptibility of diabetics to infections of all kinds may well lower their resistance to infections causing neuritis, and I have seen neuritis develop acutely in a diabetic, following an attack of pneumonia.

Pathology.

See p. 706.

Symptoms.

Loss of tendon reflexes is very common in diabetes in the absence of other signs of neuritis. Severe polyneuritis is exceptional. Sensory symptoms usually predominate over motor, and the lower limbs are more affected than the upper. Pain in the calves may be considerable. Loss of postural sensibility is often marked in the lower limbs, leading to severe ataxia. Local interstitial neuritis is not uncommon in diabetes and is most frequently seen in the external popliteal nerve. Ocular palsies occurring in diabetes have been ascribed to neuritis of the oculomotor nerves, but are more probably due to vascular lesions involving the nerves (see p. 149). In elderly diabetics the pupils are often contracted and may react sluggishly to light. Other complications of diabetes may be present, including impaired peripheral circulation, owing to arterial atheroma, which may lead to gangrene of the extremities or perforating ulcer.

Diagnosis.

The diagnosis of polyneuritis is described on p. 707. The origin of the diabetic form is settled by discovery of sugar in the urine. The symptoms of neuritis must be distinguished from those of vascular occlusion. Confusion is not likely to arise if the arterial pulse is carefully examined both in the proximal and peripheral parts of the limbs.

Prognosis.

The prognosis of diabetic neuritis is good, provided that the patient responds satisfactorily to treatment for diabetes, that vascular degeneration is not severe, and that trophic lesions, such as gangrene and perforating ulcers, are absent.

Treatment.

The usual treatment of diabetes must be carried out, including, if necessary, the use of insulin. Careful search should be made for sources of infection and the treatment appropriate to polyneuritis given (see p 707).

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HAEMATOPORPHYRINURIC POLYNEURITIS

The rare association of polyneuritis with haematoporphyrinuria is obscure, since little is known concerning the causation of haematoporphyrinuria, and we are quite ignorant as to why polyneuritis should occur in such cases Haematoporphyrinuria may occur (1) as a congenital, and sometimes hereditary, abnormality . (2) as a result of the ingestion of sulphonal, trional, and barbital (it does not usually follow the ingestion of these drugs until they have been taken for a considerable time, though rarely it may occur after a single dose) ; (3) as an acute 'idiopathic' condition of unknown origin.

There is some evidence that intestinal toxins may play a part in the production of haematoporphyrinuria, and dilatation of part of the alimentary canal has been described in a number of cases of the acute idiopathic variety. The pathological changes in the nervous system consist of degeneration of the peripheral nerves and of the ganglion cells of the anterior horns of the spinal cord, and of the posterior root ganglia

Acute idiopathic haematoporphyrinuria is ushered in by sleeplessness, pains in the limbs, and abdominal pain, which may be very severe and in a number of cases has led to an exploratory laparotomy being undertaken. The urine becomes deep red from the presence of haematoporphyrin. The character of the polyneuritis is somewhat variable, but in a number of cases an acute ascending paralysis of the Landry type has developed Delirium is common. The prognosis in haematoporphyrinuric polyneuritis is always grave and the mortality rate is said to be 50 per cent Large doses of alkali should be given and the treatment appropriate to an acute toxic polyneuritis should be carried out (see p. 707).

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ACUTE INFECTIVE POLYNEURITIS

Synonyms: Acute toxic polyneuritis; acute febrile polyneuritis; 'rheumatic' polyneuritis; syndrome of Guillain and Barré; polyradiculoneuritis.

Definition: An acute diffuse infective disease of the nervous system involving the spinal cord and peripheral nerves and occasionally the brain.

Aetiology.

Acute infective polyneuritis is a rare disease which may occur sporadically at any time. A number of cases were observed among troops during the 1914 war. (Guillain and Barré, 1916; Holmes, 1917; Bradford, Bashford, and Wilson, 1918). Most of the reported cases have occurred in males between the ages of 20 and 50 years. The acute and febrile course of the disease suggests that it is due to an infection with an organism, the toxins of which have a predilection for the lower motor neurones. It has been stated to be due to a virus, a minute rounded body measuring 0·2 to 0·5 μ in diameter, which can be cultivated, and cultures of which are said to have reproduced the disease in monkeys, but this has not been verified.

'Rheumatic' polyneuritis, a form which has been described as following exposure to cold or wet, is probably the same, or at least a closely related condition.

Pathology.

Naked-eye abnormalities are slight and consist of variable congestion of the meninges, and petechial haemorrhages in the substance of the spinal cord. Microscopically the spinal cord exhibits chromatolysis of the ganglion cells, both of the anterior horns and of the posterior roots, with slight perivascular infiltration with small, round cells The peripheral nerves, especially those containing motor fibres, show marked degenerative changes of their myelin sheaths, with proliferation of the cells of the sheath of Schwann and in some cases swelling and fragmentation of the axis cylinders. There is an inflammatory exudate with round cells and haemorrhages. In long-standing cases degenerative changes are found in the muscles. Perivascular inflammatory infiltration has been observed in the brain, and infiltration with round cells may be present in the liver,

kidneys, and lungs, the kidneys sometimes showing areas of acute nephritis.

Since there is evidence of inflammatory and degenerative changes throughout the whole course of the lower motor neurone, the condition is better described as a polyneuronitis than as a polyneuritis.

Symptoms.

There is frequently an initial febrile illness in which no nervous symptoms appear, followed by a period of latency, which may last from a few days to several weeks, at the end of which paralysis develops. In some cases the patient first comes under observation in the paralytic stage, symptoms of the initial stage being slight or absent.

The first symptoms are usually headache, vomiting, slight pyrexia, and pains in the back and limbs, which may be associated with a feeling of stiffness in the neck. The paralytic symptoms, which develop after the latent period, usually come on very suddenly, accompanied by headache and sometimes by a recurrence of the pyrexia. Less frequently the onset of the paralytic symptoms is gradual. The paralysis may affect all four limbs simultaneously or may begin in the lower limbs and spread to the upper. In contrast with other forms of polyneuritis all the muscles of a limb are usually affected, those of the proximal segment suffering as much as, or even more severely than, those of the distal segments. In severe cases the muscles of the neck and trunk are also involved, and there is almost always paralysis of the facial muscles on both sides, though this is occasionally unilateral. Dysphagia may occur as a result of pharyngeal paralysis, but the palate usually escapes. External ophthalmoplegia is occasionally seen. The paralysed muscles are flaccid, but a severe degree of wasting is exceptional. Superficial and deep reflexes are usually diminished or lost, but may be retained in spite of weakness of voluntary movement in the muscles concerned. The sensory symptoms characteristic of polyneuritis are usually present, and in the early stages the patient complains of pain, numbness, and tingling in the limbs. All forms of sensibility may be impaired over the peripheral segments of the limbs and the muscles may be tender. The sphincters are rarely involved and never to a severe extent, though there may at times be slight retention of urine necessitating catheterization. Cerebral symptoms are usually absent and consciousness is unclouded to the last, but a confusional or Korsakow's psychosis may develop.

General symptoms of toxaemia may be present, including slight cardiac dilatation and albuminuria and an erythematous rash. The blood shows a moderate polymorphonuclear leucocytosis. The charac-

teristic change in the cerebro spinal fluid is a great excess of protein with either a normal cell count, or at most only a moderate excess of mononuclear cells. This is the 'dissociation albumino-cytologique' stressed by Guillain and Barré (1916). The fluid may be yellow or brown and clot spontaneously. The high protein may persist for many weeks even after recovery.

Diagnosis.

Acute infective polyneuritis is readily distinguished from other forms of polyneuritis by the acute febrile onset, the rapid development of the paralysis, and the severe involvement of the proximal limb muscles. It is distinguished from acute anterior poliomyelitis by the symmetrical character of the paralysis, by the presence of sensory loss, and by the slightness or absence of muscular wasting in the later stages. The diagnosis from Landry's paralysis is somewhat artificial, since some cases of this condition have probably been examples of acute infective polyneuritis. In typical Landry's paralysis, however, though the motor disturbances resemble those of acute infective polyneuritis, sensory loss is slight or absent. Acute myelitis, especially the ascending form, may also cause widespread flaccid paralysis, but in this condition the plantar reflexes are usually extensor, sensory loss is more extensive and involves the whole body below the level of the lesion, and sphincter disturbances are present.

Prognosis.

The mortality of the disease is high in some epidemics, death usually occurring from paralysis of the respiratory muscles, with or without terminal broncho-pneumonia. Slight remissions are not infrequent, but are often followed by severe relapses. In sporadic cases, however, the outlook is usually good, but improvement is slow and the paralysis, having reached its height, tends to remain stationary for some weeks. In the most favourable cases the patient is not likely to be convalescent in less than from three to six months.

Treatment.

No specific treatment is available. The usual treatment of polyneuritis must be carried out (see p. 707). Much depends upon good nursing. An attempt may be made to tide the patient over an attack of respiratory paralysis by means of artificial respiration with a Drinker's or Bragg-Paul respirator. During convalescence the patient should be kept in bed as long as any weakness of the trunk muscles persists, lest exertion should cause respiratory paralysis.

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POLYNEURITIS WITH PAROTITIS AND IRIDO-CYCLITIS

This syndrome, which has been described by Feiling and Viner and others, is characterized by generalized polyneuritis involving both the limbs and the facial muscles, bilateral parotitis and bilateral irido-cyclitis, with cycloplegia. An erythematous rash may be present on the lower parts of the thighs and anterior aspects of the legs. The uveitis and parotitis are more often seen without the polyneuritis or with facial diplegia alone. Histological changes in the parotid glands resembling those of tuberculosis, but without tubercle bacilli, led to the disorder being called uveo-parotid tuberculosis, but it is now usually regarded as a form of Boeck's sarcoidosis.

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PINK DISEASE

Synonyms: Erythroedema polyneuritis, trophodermatoneurosis, vegetative neurosis, acrodynia.

Definition: A disease affecting young children, characterized by irritability, photophobia, a red discoloration, with slight swelling, of the hands and feet, and symptoms of polyneuritis.

Pathology.

The pathology of pink disease has been investigated by Greenfield and Paterson, and more recently by Wyllie and Stern. The changes in the nervous system consist of degeneration, especially of myelin, in the peripheral nerves. In the spinal cord there is chromatolysis

of the anterior horn cells, which is most apparent in the lumbo-sacral region, together with a diffuse infiltration with small cells, probably glial in origin. Exceptionally, slight infiltration has been found in the brain. Lymphocytic infiltration of the cervical sympathetic ganglia has been described. Histologically the cutaneous lesions consist of hyperkeratosis, hypertrophy of the sweat glands, and lymphocytic infiltration of the corium, with oedema.

Aetiology.

The victims of the disease are young children between the ages of 4 months and 7 years, the onset usually occurring between the ages of 9 and 18 months. Males are affected slightly more often than females. The disease is widely prevalent, but is especially common in Australia and in North America. Small local epidemics are characteristic. Most cases occur between the autumn and early spring. Some workers regard it as infective, others as a deficiency disease. A somewhat similar condition has been produced in rats by feeding them on a restricted diet, and pink disease in some respects resembles pellagra. There is no evidence, however, that it is due to a deficiency of any known vitamin. The prominence in the clinical picture of symptoms of autonomic disturbance have led to its being regarded as a disorder of the vegetative nervous system.

Symptoms.

The earliest symptoms are usually those of a mild infection of the upper respiratory tract or of the alimentary canal. Shortly afterwards the child becomes miserable and irritable and suffers from insomnia and loss of appetite. At the same time the hands and feet become bluish-red, slightly swollen, and cold. In addition there is often an erythematous rash over the face, trunk, and extremities. There is always excessive sweating and desquamation occurs on the hands and feet. The rash is extremely irritating, and the child frequently adopts a characteristic posture, crouching in bed with the knees drawn up and its face buried in the pillow, to shield it from the light.

In severe cases trophic disturbances are present, including ulceration of the mouth, falling-out of teeth and nails and of the hair.

There is no true paralysis, but the muscles become extremely hypotonic, and in chronic cases the tendon reflexes are lost and analgesia of peripheral distribution may be demonstrable.

Pyrexia is absent after the prodromal stage. The pulse is rapid and the blood-pressure may be slightly raised. The urine may contain a trace of albumin. The cerebro-spinal fluid is normal, but the blood shows a leucocytosis.

Diagnosis.

The combination of symptoms and their occurrence in early childhood are unique, and the condition is, therefore, unlikely to be confused with any other.

Prognosis.

The mortality is low, approximately 5 per cent., death being due to cardiac failure, or more usually to an intercurrent infection, such as broncho-pneumonia. The disease runs a chronic course and usually lasts from three months to a year.

Treatment.

Treatment is mainly symptomatic, though Wyllie and Stern have stated that benefit has been derived from liver, 2 oz. of pounded raw liver being given daily. Much depends upon care in nursing and feeding, and in severe cases to overcome the anorexia it may be necessary to feed the child through a stomach tube. Small doses of phenobarbital constitute the best treatment for the irritability and sleeplessness. Frequent sponging and change of clothing will be necessary on account of the sweating, and the child's hands and feet must be secured in gloves and socks to prevent scratching.

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DIPHTHERIA

Aetiology.

Neuritis is the commonest and most important of the nervous complications of diphtheria, the exotoxin of the Klebs-Loeffler bacillus having an affinity for the peripheral nerves. It is most frequently observed during childhood and is rare in adult life. According to Rolleston, in spite of the general belief to the contrary, the occurrence of paralysis bears a definite relationship to the severity of the local infection, which is usually faucial but may be extrafaucial. The introduction of antitoxin has greatly reduced the incidence of paralysis, which is almost unknown in patients who have received antitoxin on the first day of their illness, and becomes progressively more frequent the longer the administration of this remedy is delayed.

Palatal paralysis is usually attributed to the ascent of the toxin from the common faucial site of infection to the medulla, though

Rolleston states that when paralysis of the palate develops early it is due to myositis. A local ascent of the nerves by the toxin is responsible for the local development of paralysis following a cutaneous infection, the muscles paralysed being those supplied by the spinal segment from which the infected region is innervated (Walshe, 1918–19). Paralysis of accommodation and generalized polyneuritis are due to the dissemination of the toxin by the blood-stream to the ciliary muscle and the peripheral nerves.

Pathology.

The pathology of the neuritis has no peculiar features and has already been described (see p. 706). Hemiplegia, a rare complication of diphtheria, appears usually to be due to a vascular lesion, either embolism or thrombosis of a cerebral artery, or to an area of so-called acute haemorrhagic encephalitis.

Symptoms.

Paralysis of the palate, which is usually the earliest nervous symptom, may occur within a few days of the onset of the infection. Usually, however, it develops during the second or third week. It is generally bilateral but may be unilateral. It causes the voice to acquire a nasal character and leads to regurgitation of fluids through the nose on swallowing. The palatal reflex is usually lost.

Paralysis of accommodation develops as a rule during the third or fourth week and leads to dimness of vision for near objects. It is usually bilateral, very rarely unilateral, and may pass unnoticed in myopic subjects who do not require to accommodate for near vision. The pupillary reactions to light and on convergence are unimpaired. Paresis of external ocular muscles is not very rare, the external rectus being most often affected.

The symptoms of generalized polyneuritis, which are not always preceded by paralysis of the palate and of accommodation, do not develop until between the fifth and seventh week after infection. At this stage paralysis of the constrictors of the pharynx, of the intrinsic muscles of the larynx, associated with laryngeal anaesthesia, and paralysis of the diaphragm are the most serious complications, on account of the dysphagia and dyspnoea to which they lead. The adductors of the vocal cords are more often paralysed than the abductors. Paralysis of the neck muscles may occur.

The lower limbs are usually more severely affected than the upper, and movements of peripheral segments suffer more than those of proximal segments. Sensory loss is common, cutaneous anaesthesia and analgesia of the 'glove and stocking' distribution being asso-ciated with tenderness of the muscles on pressure. Postural sensi-

y is often grossly impaired, leading to marked ataxia, especially
he lower limbs, the so-called 'pseudo-tabetic' form of diphtheritic
lysis.

he tendon reflexes are lost early and may remain absent for
iths or even for years. Loss of the tendon reflexes may occur
he absence of other symptoms of polyneuritis and, with or with-
palatal palsy, may constitute the only nervous symptoms of
theria. The plantar reflexes may be unobtainable but are usually
or, though Rolleston has drawn attention to the occurrence of
ensor plantar responses, an indication that the pyramidal tracts
involved in the intoxication. The sphincters are usually un-
cted, but impotence has frequently been described. The 'cardiac
lysis' of the early stages is probably due to the effect of the
in on the myocardium, but at any stage tachycardia may occur
result of vagal paralysis. The cerebro-spinal fluid may be normal
ts protein content may be increased.

iphtheritic hemiplegia is fortunately rare. The symptoms are
ilar to those of other acquired forms of infantile hemiplegia (see
553). Meningism is not very uncommon in the acute stage of
htheria. Cervical rigidity or opisthotonos may be associated with
dity of the limbs, so-called 'spasmodic diphtheria.' The cerebro-
nal fluid in such cases, though its pressure may be increased, is
mal in composition. Permanent bulbar palsy is a rare sequel of
htheria.

ignosis.

'or the diagnosis of polyneuritis see p. 707. The diphtheritic
m is usually easily recognized on account of the age of the patient
l the occurrence of such characteristic features as palatal paralysis
l paralysis of accommodation. The diphtheria bacillus should
ays be sought at the site of infection, but may be absent. In
ibtful cases the Schick test may be of diagnostic value, since a
ative reaction indicates that the patient probably has not had
htheria. A negative reaction, however, is of little significance

ognosis.

The prognosis of the paralysis is usually good if the child survives.
ralysis of the palate and of accommodation disappears in from
ee to six weeks, and recovery from the paralysis of the limbs is
ally complete, though this may take several months. Paralysis
the pharynx, larynx, and diaphragm, though equally recoverable,
f serious import owing to the risk of broncho-pneumonia which it
volves. Permanent paralysis of the limbs is fortunately very rare,
t I have seen one case. Hemiplegia is a serious complication, as

not only may it prove fatal, but in patients who survive recovery is usually incomplete, and epilepsy and mental defect may occur as sequels.

Treatment.

The routine treatment of diphtheria includes injection of adequate doses of antitoxin as early as possible. If this has been carried out, the administration of further doses when paralysis develops is of doubtful value. Paralysis of the limbs should be treated on the lines laid down for the treatment of polyneuritis (see p. 707). Paralysis of the pharynx and larynx necessitates special care in feeding. Food should be of the consistency of porridge, and if, in spite of this, coughing occurs, it will be necessary to employ nasal feeding. Such patients often derive benefit from the injection of atropine sulphate, gr. 1/100th, combined with strychnine sulphate, gr. 1/60th to 1/30th, twice or three times a day. Cardiac stimulants may be required, and respiratory paralysis should be treated with a Drinker or similar respirator.

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LEPROUS NEURITIS

Aetiology.

Leprosy is due to infection with the bacillus leprae of Hansen, an acid-fast bacillus, staining like the tubercle bacillus by Ziehl-Neelsen's method. The mode of infection is uncertain, but the disease is probably contagious. The organism has a predilection for the mucous membranes and peripheral nerves. Nodular, anaesthetic, and mixed forms occur. The anaesthetic form alone will be described here.

Pathology.

The characteristic lesion is a granuloma, the leprous nodule, composed of large connective-tissue cells, the lepra-cells, containing the lepra bacilli and surrounded by epithelioid and plasma-cells and fibroblasts. The peripheral nerves are invaded by the nodules, the infection usually beginning at the periphery and gradually ascending the nerve, leading to marked irregular thickening. The axis cylinders and later the myelin sheaths degenerate. The posterior root ganglia, the Gasserian ganglia, the sympathetic ganglia, and the anterior horns

of the spinal cord may be invaded, and within the cord fibres derived from the posterior root ganglia undergo degeneration.

Symptoms.

The onset of symptoms is gradual Prodromal symptoms of a toxaemic nature may be present. These are followed by pains referred to the distribution of the peripheral nerves in the limbs and often by a sense of numbness of the extremities. *Symptoms tend to be symmetrical, anaesthesia of the 'glove and stocking' distribution developing, together with atrophic paralysis of the muscles of the peripheral segments of the limbs. Facial anaesthesia and paralysis due to involvement of the fifth and seventh cranial nerves are not uncommon. Trophic changes are conspicuous in the limbs. Bullae, ulceration, and necrosis of the phalanges occur, and the fingers may all be lost. Thickening of the peripheral nerves is usually, but not invariably, palpable.*

Diagnosis.

Leprous neuritis must be distinguished from other forms of polyneuritis, especially from progressive hypertrophic polyneuritis, in which also palpable thickening of the peripheral nerves may occur, from syringomyelia, and from Raynaud's disease.

Prognosis.

The prognosis is bad, as the disease is invariably progressive in spite of treatment. In the anaesthetic form the average expectation of life is said to be ten years after the onset of symptoms.

Treatment.

For the treatment of leprosy the reader is referred to text-books of tropical medicine.

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PROGRESSIVE HYPERTROPHIC POLYNEURITIS

Definition: A rare disease, frequently familial, characterized by conspicuous enlargement of the peripheral nerves, associated with the

symptoms of *slowly progressive polyneuritis and sometimes with other abnormalities.* The disease was first described in 1889 by Gombault and Mallet, but is usually associated with the names of Dejerine and Sottas, who reported two cases in 1893.

Pathology.

There is a great increase in the volume of the peripheral nerves, though some may be affected more than others. The sciatic nerve in a case reported by Harris and Newcomb measured 1½ in. in diameter. In addition to the nerves of the limbs the cranial nerves may be involved, and similar changes have been described in the sympathetic nerves, the cauda equina, and the spinal roots. The thickening is principally due to hypertrophy and proliferation of the cells of the sheath of Schwann, which may coalesce into masses penetrated by nerve-fibres or may be flattened into layers resembling an onion. The interfibrillar connective tissue of the nerve-sheaths also undergoes hypertrophy, though to a less extent. The myelin sheaths of the nerves degenerate, especially peripherally. Degeneration of the axis cylinders is variable. Plasmatic swellings of spinal ganglia have been described. Within the spinal cord degeneration of the posterior columns is frequently, but not invariably, present, and is probably secondary to the changes in the nerves. It is most marked in the lumbo-sacral region and in the cervical cord is confined to the column of Goll. *The muscles exhibit a simple atrophy.*

Aetiology.

Although sporadic cases occur, the disease is usually familial and may be hereditary. Russell and Garland have described fully developed or abortive cases in four generations of the same family. Although it is described as polyneuritis, it is unlikely that it is inflammatory in nature. *Some authorities have considered* that it resembles peroneal muscular atrophy, but it seems more closely related to neurofibromatosis. The onset of symptoms usually occurs in childhood, but exceptionally has been deferred until adult life.

Symptoms.

Sensory symptoms are usually prominent in the early stages, and patients frequently complain of shooting pains in the limbs, which may be associated with a sense of numbness in the hands and feet. Difficulty in walking is often an early complaint. Muscular weakness and wasting develop as in polyneuritis symmetrically in the peripheral muscles of the limbs. Either the hands or the feet may be first affected, or both may suffer simultaneously. The wasting rarely

extends above the knees or the elbows. Coarse fibrillation is frequently present in the affected muscles, which exhibit the reaction of degeneration. Claw-hand and claw-foot may follow the muscular atrophy, but pes cavus may be present as a congenital abnormality.

Cutaneous sensory loss of the 'glove and stocking' distribution is found, and postural sensibility is also impaired.

Argyll Robertson pupils have been described in a small proportion of cases, and the pupils, though reacting normally, may be small, probably on account of oculo-sympathetic paralysis. Nystagmus is frequently present. The deep reflexes are diminished or lost in the affected muscles; the plantar reflexes may be lost; exceptionally extensor plantar reflexes have been described. Kyphoscoliosis is sometimes present, and arthropathic changes have been observed in the joints of the limbs. Palpable thickening of the peripheral nerves is a valuable diagnostic sign but is not invariably present.

Diagnosis.

There is little difficulty in making a correct diagnosis in a patient presenting the symptoms of a slowly progressive polyneuritis and in whom the peripheral nerves are thickened. The only common condition in which comparable thickening of the nerves occurs is neurofibromatosis, and in this disease it is rare to find palpable thickening of the deep nerves, such as the ulnar, and polyneuritic symptoms are absent. When no thickening of the nerves can be felt, hypertrophic neuritis requires to be distinguished from other forms of polyneuritis. From these it can be differentiated by its familial incidence, onset in childhood, and slow progressive course, and by the absence of the common causes of polyneuritis. Unless thickening of the nerves can be felt, it may be difficult or impossible to distinguish it from peroneal muscular atrophy. Biopsy of a superficial cutaneous nerve may settle the diagnosis.

Prognosis.

The course of the disease is extremely slow and is usually steadily progressive, though Harris and Newcomb have described a case in which remissions occurred. When the onset is in childhood patients usually survive to adult life, becoming increasingly crippled, and finally bedridden. Death usually occurs from some intercurrent disease.

Treatment.

No treatment is known to influence the course of the disease, but treatment on the lines indicated for polyneuritis will help to maintain the power of the limbs as long as possible.

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CHRONIC PROGRESSIVE POLYNEURITIS

The term 'chronic progressive polyneuritis' or 'slow chronic polyneuritis' (Harris) has been applied to rare cases of polyneuritis which *cannot be attributed to any of the common toxic causes and which run a slowly progressive course*. Nothing is known about the causation of this condition, but it may be found to be due to deficiency of vitamin B 1. The pathological changes in the nervous system consist of widespread degeneration of the peripheral nerves, especially of their motor fibres. There is progressive weakness of the limbs, associated with some wasting, especially of the peripheral segments, and sensory loss of the type characteristic of polyneuritis. Pain is often less severe than in the more rapidly developing forms. The cranial nerves may be involved in the later stages, leading to dysarthria and dysphagia. Increase in the severity of the symptoms *continues for a number of months and the disease may terminate fatally*, as in one patient whom I saw and whose case, with a pathological examination, has been reported by Hyland and Russell. Complete recovery, however, may occur or the disorder may become arrested, leaving the patient with some permanent muscular weakness, associated with contractures, as in another of my patients, in whom gastric achylia was present. Careful search must be made for possible sources of exogenous and endogenous intoxication. The gastric contents should be investigated. The treatment of polyneuritis due to vitamin B 1 deficiency should be carried out.

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RECURRENT POLYNEURITIS

Recurrent or relapsing polyneuritis is a rare form of polyneuritis, in which repeated attacks occur, usually separated by intervals of

several years. Only a small number of such cases have been reported. *Migley (1933) has reviewed the literature and reported three members of the same family who suffered from recurrent polyneuritis in pregnancy and the puerperium. One of my patients was a boy of 15,* whom I saw in his fourth attack, the first having occurred when he was 4 years of age, and each attack being followed by complete recovery. In a middle-aged woman, who was seen in her third attack, *there was some permanent muscular wasting and weakness* No cause can be found. The recurrent form appears to be closely related to the chronic progressive variety and should receive the same treatment.

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POLYNEURITIS CRANIALIS

The term 'polyneuritis cranialis' has been used in two senses.

(1) Certain of the cranial nerves may be involved in polyneuritis in association with the nerves of the limbs. The cranial nerves are commonly attacked in acute infective polyneuritis, but there is probably no form of polyneuritis in which cranial nerves may not suffer. They are usually symmetrically affected. The facial nerve is most frequently involved, leading to facial paralysis, which is usually bilateral, and next in frequency the bulbar nerves, leading to dysphagia, and the trigeminal The oculomotor nerves are less frequently affected, and the optic nerves usually escape, though I have twice seen bilateral optic neuritis associated with severe polyneuritis. Exceptionally the cranial nerves may be alone affected in polyneuritis or there may be only slight involvement of the nerves of the limbs, indicated by paraesthesiae or diminution in the tendon reflexes.

(2) The term 'polyneuritis cranialis' has also been applied to an inflammatory lesion of multiple cranial nerves within the skull. This usually follows osteomyelitis of the bones of the base of the skull or basal pachymeningitis secondary to chronic otitis media. In such cases the affection of the cranial nerves is usually unilateral. The lesion may involve the anterior group, third, fourth, fifth, and sixth, or the posterior group, seventh to twelfth, but in some cases almost all the nerves may suffer. This condition must be distinguished from compression of multiple cranial nerves by neoplastic infiltration of the meninges.

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POLYNEURITIS DUE TO PERIARTERITIS NODOSA

Though periarteritis nodosa is an uncommon disease it deserves mention because the presenting symptoms may be those of involvement of the peripheral nerves.

This disorder, which is probably due to an infection, is characterized by a lesion in the arteries which begins with necrosis of the media and the internal elastic lamina which is followed by extension of the inflammation to the adventitia and by periarteritis. Proliferation of the intima produces gradual narrowing of the lumen of the vessel. Secondary aneurysm formation is exceptional. Degeneration of the peripheral nerves is secondary to the damage to the nutrient arteries. Similar lesions may occur in the brain and spinal cord.

The symptoms of involvement of the peripheral nerves are those of multiple interstitial neuritis rather than toxic polyneuritis. Pain, tenderness of the nerve trunks and muscles with muscular wasting and weakness, loss of reflexes, and sensory loss are irregularly distributed according to the distribution of the nerves affected. Retinal vascular lesions may occur and cerebral lesions may lead to headache, convulsions, hemiplegia, mental dullness, and coma. The spinal fluid may be under increased pressure and there may be xanthochromia and a polymorphonuclear leucocytosis.

The general symptoms are those of a serious infection with fever, loss of weight, and focal visceral symptoms depending upon the situation of the lesions which tend to involve especially the kidneys, heart, liver, and gastro-intestinal tract. The blood may show a leucocytosis and occasionally an eosinophilia. In most cases there is hypertension.

REFERENCE

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DISORDERS OF PERIPHERAL NERVES

1. TUMOURS OF NERVES

THE connective tissue of a peripheral nerve may be the site of a tumour, either benign—a fibroma, or malignant—a sarcoma. Such tumours do not differ from similar tumours elsewhere, and their relationship to the nerve is in a sense accidental. Tumours peculiar to peripheral nerves consist of tumours arising from the nerve elements and those arising from the nerve-sheaths. Primary tumours of the nerve elements are extremely rare, but a neuro-epithelioma has occasionally been described on a peripheral nerve. The perineurial fibroblastoma is a tumour arising from the nerve-sheath It is seen in several syndromes, variants of neurofibroblastomatosis, of which von Recklinghausen's disease is the best known (see p 562)

2. LESIONS OF PERIPHERAL NERVES

· GENERAL CONSIDERATIONS

Symptoms of Complete Division.

Complete division of a mixed peripheral nerve causes motor, *sensory, vasomotor, and trophic symptoms corresponding to the region in which these functions are supplied by the divided nerve.*

(1) *Motor Symptoms.*

Interruption of the motor fibres of the nerve leads to a lower motor neurone paralysis of the muscles which it innervates The muscles innervated exhibit a flaccid paralysis and rapidly waste The reflexes in which they participate are diminished or lost, and reaction of degeneration develops. Investigation of the motor functions of a nerve involves testing the patient's power to contract the muscles both as prime movers and also as synergists. The observer must be on his guard to detect trick movements, for it is frequently possible for a movement which is normally effected by a *paralysed muscle to be carried out by another muscle when the* segment of the limb is first placed in an appropriate position. The *electrical reactions of the muscles must also be tested, and in the* case of the small muscles of the hand electrical testing often gives more reliable information as to the extent of paralysis than does voluntary movement.

(2) *Sensation.*

The methods of carrying out tests of sensibility are described elsewhere; see pp. 23-6. Division of a sensory nerve causes complete loss of sensibility only over the area exclusively supplied by the nerve. The cutaneous area over which appreciation of light touch is lost is usually considerably greater than the area characterized by a loss of appreciation of pin-prick. In investigating the former the area of skin to be tested should always be shaved. The area over which appreciation of pin-prick is lost is often ill-defined and merges gradually into areas in which this form of sensibility is present, though grossly impaired. In some cases, even of complete division of a nerve, the completely analgesic area is surrounded by a zone in which, although a stronger stimulus than normal is necessary to evoke pain, the painful sensation is more than usually disagreeable. The term 'deep sensibility' is used to include the appreciation and localization of pressure and the pain induced by deep pressure and the recognition of posture and passive movements of the joints. According to Head, fibres subserving these forms of sensibility in the upper limb leave the peripheral nerves in the forearm and subsequently pass downwards with the tendons. Hence deep sensibility is not likely to be lost on the fingers when the median or ulnar nerves are divided at the wrist, as long as the tendons are intact. Stopford, however, has demonstrated that, although some fibres concerned in deep sensibility may pass with the tendons, others undoubtedly go with the digital branches of the median and ulnar nerves, and he has observed an impairment of deep sensibility in the distal parts of the digits after division of these nerves at the wrist. It is generally agreed, however, that impairment of deep sensibility, when present as a result of nerve division, is confined to a peripheral area which is less extensive than the area anaesthetic to light touch.

(3) *Vasomotor and Trophic Functions.*

Vasomotor and trophic disturbances which follow destruction of a motor or a mixed nerve are probably due, at least in part, to the interruption of efferent sympathetic fibres concerned in vasoconstriction. These disturbances are most marked after injuries of the median, ulnar, and sciatic nerves. After complete division of a nerve the analgesic area of skin becomes dry and inelastic and ceases to sweat. The surface becomes scaly owing to retardation of desquamation; the affected area is blue and colder than normal, especially in cold weather; and the limb becomes oedematous when it is allowed to hang down. The analgesic area is exceptionally liable to injury, and when injured heals slowly, so that ulcers may develop. The growth

of the nails is retarded. Adhesions between tendons and their sheaths and fibrous changes in the muscles and joints are to be regarded as complications rather than as direct results of the nerve injury, since they can be prevented by massage and movement of the joints.

Symptoms of Recovery.

Recovery of function after complete division of a nerve occurs by means of a down-growth of the nerve-fibres from the central end, and can therefore take place only when the divided ends lie in apposition or have been brought together by suture. The time required for recovery depends principally upon the distance which the regenerating fibres have to travel from the site of injury to their normal destinations. There has been much theoretical discussion concerning the interpretation of the sensory changes which characterize returning function, but there is considerable agreement as to the facts. The first indication that nerve-fibres have passed into the distal part of the nerve may be a peculiar sensitiveness of the nerve-trunk below the site of the union. Mechanical stimulation readily evokes a tingling sensation which is referred by the patient into the territory of the nerve (Tinel's sign). Before other objective signs of recovery appear the patient may say that the part feels more life-like or is less numb. The first objective sign of returning function is a diminution in the area of impairment of deep sensibility. Painful sensibility returns next, but for a long time exhibits characteristics which distinguish it from normal painful feeling. During this stage of recovery, a stronger stimulus than normal may be required to evoke pain, but the response is of a peculiarly unpleasant quality, and is a diffuse and badly localized sensation. Somewhat later the affected area becomes sensitive to the extremes of heat and cold. The appreciation of light touch and its accurate localization do not recover until many months after the return of painful sensibility, and frequently never recover completely. When recovery of appreciation of light touch occurs it is associated with the disappearance of the uncomfortable and irradiating character of painful sensibility. Head has termed the form of sensation which first recovers 'protopathic sensibility' and the form which recovers later 'epicritic sensibility' and has attributed a biological significance to this distinction. Other workers, however, have drawn attention to the obstacles in the way of complete return of function in regenerating nerve-fibres after section of the nerve and attribute the peculiarities of the protopathic stage of recovery to abnormalities in the insulation of the pain-fibres.

With the return of painful sensibility, vasomotor changes become less conspicuous and the skin heals more readily. There is frequently

pads are wasted, so that the nail-beds protrude; the joints are stiff and swollen and the bones rarefied and brittle. Tenderness may be evoked either by superficial or by deep stimulation or by both, in a small proportion of cases only by the latter. Superficial tenderness usually extends over the whole cutaneous area innervated by the nerve and thus is more extensive than the area of anaesthesia produced by nerve section, which corresponds to the area exclusively supplied by the nerve. The affected nerve may be tender throughout the whole length of the limb, even as high as the brachial plexus. There may be little or no associated muscular paralysis. Owing to the extreme tenderness of the affected part the patient makes every effort to protect the limb from all forms of external stimulation. Similar symptoms may be referred to the stump following amputation.

The recent work of Lewis (1937) suggests that causalgia may be due to irritation of nerves of the nocifensor system running to the skin, as a result of which a substance is discharged which lowers the threshold of the pain fibres.

Treatment.

The satisfactory treatment of causalgia is always difficult. The most effective method of relieving the pain is to excise the damaged portion of nerve and resuture it. This means, however, substituting for an incomplete lesion a complete one, with prolonged, and possibly permanent, disability. On the other hand, if medical treatment is unsuccessful and operation is to be undertaken months after the injury, excision of the damaged portion of nerve may be of no benefit and the pain may persist even after interruption of the spino-thalamic tract in the spinal cord. Generally it is wise to begin with medical measures and review the position after a month or two. If the patient is then standing the pain well and getting adequate sleep, *the outlook for medical treatment is good. If, however, he is not making progress and especially if he is a neurotic individual, surgical treatment should be carried out.*

When medical treatment is employed the position should be *explained to the patient and his intelligent co-operation obtained.* Moist local applications usually give most relief and should be used at the temperature which the patient finds most comforting. Sometimes relief is obtained from painting the affected part with a mixture of equal parts of camphor, menthol, and chloral. The following mixture is a valuable one:

R.	Potassium bromide .	.	.	.	gr. 10
	Tincture of gelsemium	.	.	.	♏. 10
	Phenazone .	.	.	.	gr. 7½
	Water to ½ oz., thrice daily.				

Aspirin and pyramidon, āā gr. 5, may be given as required, with the addition, if necessary, of heroin, gr. 1/12th, but the risk of heroin addiction must always be kept in mind. Phenobarbital, gr. 1, barbital, gr. 4, or soluble barbital, gr. 7½, may be required to ensure sleep. To avoid diminishing the patient's resistance to pain, drugs should as far as possible be given only at night

The limb should not be immobilized. Massage and passive movements should be carried out as far as they can be tolerated. Electricity is of little or no value, but therapeutic X-ray irradiation of the damaged nerve should be tried

If operative treatment is decided upon, either the damaged area of the nerve must be excised and the nerve sutured, or the nerve must be injected with alcohol above the level of the lesion A 70 per cent solution appears to give as good relief of pain as absolute alcohol is likely to cause less severe degeneration If local operation fails to give relief, section of the posterior roots or of the opposite spinothalamic tract in the spinal cord must be considered, but these *measures will often prove ineffective* If posterior root section is *to* be done, it must be carried out on a large scale, and nothing can be hoped from this operation unless *not only* those roots supplying the limb but also two or three above and below are divided

Causalgic symptoms in amputation stumps in the absence of active infection are usually due to painful nerve-bulbs and should be dealt *with by dividing the nerve as high above the bulb as possible, crushing* and ligaturing the end, and injecting the nerve with absolute alcohol

3 SYMPTOMS AND TREATMENT OF INDIVIDUAL NERVE LESIONS

THE PHRENIC NERVE

The phrenic nerve is derived from the anterior primary divisions of the third, fourth, and fifth cervical spinal nerves, the main contribution coming from the fourth. It is the motor nerve to the diaphragm. Irritation of the phrenic nerve causes a dry, unproductive, 'barking' cough. Rarely it may cause hiccup. Paralysis of the nerve causes loss of movement of the diaphragm on the affected side. The effects of this are most evident when the lesion is bilateral The diaphragm fails to descend on inspiration and may actually be *drawn upwards.* There is increased eversion of the costal margins with indrawing of the upper abdominal wall on inspiration. Diaphragmatic paralysis causes no symptoms as long as the patient is at rest, but dyspnoea may occur on exertion. The resulting diminution in expansion of the bases of the lungs renders the patient liable to develop a basal broncho-pneumonia.

Diaphragmatic paralysis is most frequently produced by lesions, involving the anterior horn cells of the spinal cord in the third, fourth, and fifth cervical segments, for example, acute anterior poliomyelitis, Landry's paralysis, and tumours of the spinal cord. The phrenic nerve may be intentionally divided for therapeutic purposes or injured during operations on the neck and may be compressed by aneurysm of the aorta and by intrathoracic neoplasms and enlargement of the mediastinal glands. It may undergo degeneration in polyneuritis due to alcohol, diphtheria, lead, or other toxins

THE NERVES OF THE UPPER LIMB

THE BRACHIAL PLEXUS

The brachial plexus is formed from the anterior primary divisions of the fifth, sixth, seventh, and eighth cervical and the first dorsal spinal nerves. It sometimes receives a contribution from the second dorsal nerve. Variations in the position of the brachial plexus are not uncommon. In the so-called 'prefixed' type there is a contribution from the fourth cervical nerve; the fifth cervical branch is large and there may be no branch from the second dorsal. In the 'postfixed' type there may be no branch from the fourth cervical and that from the fifth is comparatively small, whereas the second dorsal branch is quite distinct. The spinal segmental representation of muscles may be slightly higher or slightly lower than normal according to whether the plexus is prefixed or postfixed.

The contributions to the plexus from the anterior primary divisions soon divide into anterior and posterior trunks, and from these are formed the three cords of the plexus. The outer cord is formed by a union of the anterior trunks of the fifth, sixth, and seventh nerves. From it arise the external anterior thoracic and musculo-cutaneous nerves and the lateral head of the median nerve. The inner cord is formed by a combination of the anterior trunk of the eighth cervical with the contribution of the first dorsal nerve to the plexus. It supplies the medial head of the median nerve, the ulnar nerve, the internal cutaneous and lesser internal cutaneous nerves, and the internal anterior thoracic nerve. The posterior cord is formed by the union of the posterior trunks from the fifth, sixth, seventh, and eighth cervical and sometimes the first dorsal nerves. It gives rise to the circumflex and musculo-spiral nerves, the two subscapular nerves, and the nerve to the teres major.

Certain muscles are innervated by nerves which leave the brachial plexus proximal to the formation of the three cords. The most important of these are: the posterior scapular nerve, from the fifth cervical, which supplies the levator anguli scapulae and the rhomboid

muscles; the posterior or long thoracic nerve, from the fifth, sixth, and seventh cervical nerves, which supplies the serratus magnus; and the suprascapular nerve, from the fifth and sixth cervical nerves, which supplies the supraspinatus and the infraspinatus.

Lesions of the Brachial Plexus.

The brachial plexus is liable to be damaged by stabs and gun-shot wounds, by fracture of the clavicle, and by dislocation of the upper end of the humerus. Its component parts may be torn by forcible separation of the head and shoulder or by abduction of the arm. The inner cord may be compressed by a cervical rib. The plexus is occasionally involved in neoplastic deposits and may be the site of interstitial neuritis. The character of the motor and sensory disturbances resulting from lesions of the brachial plexus depends upon the situation of the lesion and the part of the plexus involved.

Total Plexus Paralysis.

This is a rare occurrence. When the lesion is close to the vertebral column all the muscles supplied by the plexus will be paralysed and the cervical sympathetic may also be involved. When the plexus is involved at the level of the cords the spinati, rhomboids, serratus magnus, pectorals, and cervical sympathetic may escape. Appreciation of light touch, pain, and temperature is lost over the forearm and hand and over the outer surface of the arm in its lower two-thirds. Postural sensibility and appreciation of passive movement are lost in the fingers. All the tendon reflexes in the upper limb are lost.

Upper Plexus Paralysis (Erb-Duchenne type)

This is due to a lesion of the branch from the fifth cervical nerve to the brachial plexus. Occasionally the sixth cervical contribution may be involved, but this is exceptional. Upper plexus paralysis is usually the result of indirect violence, the nerve being torn by undue separation of the head and shoulder. It is a common form of birth injury resulting from traction on the head when there is difficulty in delivering one shoulder. It may occur in adults as a result of a fall on the shoulder, forcing the head to one side, and occasionally follows an anaesthetic in patients in whom during the operation the arm has been held abducted and externally rotated. The muscles paralysed as a result of interruption of the fifth cervical branch are the biceps, deltoid, brachialis anticus, supinator longus, supraspinatus, infraspinatus, and the rhomboids. When the sixth cervical branch is involved in addition, there may be weakness, but not as a rule complete paralysis, of the serratus magnus, latissimus dorsi, triceps, and pectoralis major.

The position of the limb resulting from upper plexus paralysis is characteristic. It hangs at the side internally rotated at the shoulder, with the elbow extended and the forearm pronated. There is wasting of the paralysed muscles. Paralysis of the deltoid renders abduction at the shoulder impossible. The elbow cannot be flexed on account of paralysis of the flexors. External rotation at the shoulder is lost owing to paralysis of the spinati. Movements of the wrist and fingers are unaffected. The biceps and supinator jerks are lost. Sensory loss may be absent, but there is sometimes a small area of anaesthesia and analgesia overlying the deltoid.

The results of operative treatment of upper plexus paralysis are disappointing, and surgical intervention is inadvisable, except in those rare instances in which the upper part of the plexus has been divided by a stab or gun-shot wound. The arm should be put up in a splint in a position of abduction at the shoulder with the elbow flexed to a right angle and the forearm midway between pronation and supination, and the usual after-treatment of peripheral nerve lesions should be carried out. The prognosis is good, especially when the cause of the paralysis is birth injury. Complete recovery occurs in at least 50 per cent. of cases. In infants recovery is often rapid and may be complete in from three to six months. In adults it may take as long as two years.

Lower Plexus Paralysis (Dejerine-Klumpke type).

The contribution of the first dorsal nerve to the brachial plexus may be torn as a result of traction on the arm when it is in an abducted position. Lower plexus paralysis is sometimes encountered as a result of birth injury, or may be produced by a fall during which the patient endeavours to save himself by clutching something with the hand. The first dorsal nerve is usually affected alone, but the eighth cervical may also be involved. The resulting paralysis and wasting involves all the small muscles of the hand, a claw-hand resulting from the unopposed action of the long flexors and extensors of the fingers. When the eighth cervical nerve is also involved there may be wasting and weakness of the ulnar flexors of the wrist and fingers. Cutaneous anaesthesia and analgesia are present in a narrow zone along the ulnar border of the hand and for a variable distance up the forearm. There is frequently an associated paralysis of the cervical sympathetic.

Lesions of the Cords of the Plexus.

The effects of lesions of the cords of the plexus can readily be deduced from a knowledge of their respective contributions to the nerves of the upper limb which have already been described.

The Outer Cord. The outer cord is occasionally injured in dislocations of the humerus. Its interruption causes paralysis of the biceps, coraco-brachialis, and all the muscles supplied by the median nerve, *except the intrinsic muscles of the hand. Sensation is affected to a* variable extent on the radial aspect of the forearm.

The Posterior Cord. This is rarely damaged. A lesion of the posterior cord causes paralysis of the muscles supplied by the circumflex and musculo-spiral nerves, and loss of sensibility over the areas of their cutaneous supply.

Middle plexus paralysis is also rare and is equivalent to interruption of the posterior cord with the addition of paralysis of the latissimus dorsi as a result of involvement of the long subscapular nerve

The Inner Cord. Injury to the inner cord of the plexus is most commonly produced by subcoracoid dislocation of the humerus It causes paralysis of the muscles supplied by the ulnar nerve, together with the intrinsic muscles of the hand supplied by the median. Sensory loss occurs along the ulnar border of the hand and forearm Treatment is that of the individual nerves involved

CERVICAL RIB

Aetiology.

In certain circumstances the contribution from the first dorsal nerve to the brachial plexus may be compressed by a cervical rib or even by a normal first rib. A prefixed plexus is not infrequently associated with the presence of a rudimentary rib derived from the seventh cervical vertebra In such cases the contribution to the plexus from the first dorsal nerve may be compressed as it passes over the rudimentary rib, or, in the absence of such a rib, over an enlarged seventh cervical transverse process or over a fibrous band uniting either a cervical rib or the transverse process to the first rib. When the plexus is postfixed the contribution from the first and second dorsal nerves is relatively large, and forms a cord which may be compressed by the normal first rib. It must be remembered, however, that cervical ribs are frequently present without causing symptoms. In fact it has been estimated that symptoms occur in only 5 to 10 per cent of cases. Moreover, cervical ribs are usually bilateral, but symptoms are usually produced on one side only, mostly the right, and not infrequently the patient complains of symptoms on the side upon which, according to radiograms, the smaller rib is found. Although cervical ribs are congenital, symptoms usually do not appear until adult life. It is probable, therefore, that the mere presence of the rib is as a rule insufficient to produce symptoms. Dropping of the shoulder girdle, associated with loss of muscle-tone, tends to increase the pressure of the nerve on the rib and the effect

of prolonged pressure is cumulative, causing a pressure neuritis.
Women suffer more frequently than men.

Symptoms.

The onset is usually gradual and the symptoms of which the
patient complains may be mainly sensory, motor, or vascular, or
a combination of these may be present. The commonest sensory
symptom is pain, which is referred to the ulnar border of the hand
and distal half of the forearm and may be associated with numbness,
tingling, or other paraesthesiae. Typically the pain is relieved by
raising the hand above the head, which diminishes the pressure of
the nerve upon the rib. Careful sensory investigation frequently
reveals either hyperalgesia or relative analgesia in a narrow zone
corresponding to the cutaneous distribution of the first dorsal seg-
ment along the ulnar border of the hand and of the distal part of the
forearm. Exceptionally, pain in the neck and at the site of the rib may
be the only symptom of which complaint is made. Motor symptoms
consist of weakness and wasting, the distribution of which depends
in part upon the position of the plexus. It is usually confined to the
small muscles of the hand, and may begin either in those supplied by
the median or in those supplied by the ulnar nerve. Less frequently
the muscles of the ulnar side of the forearm are affected, and this is
most likely to occur when the plexus is postfixed. Vascular symptoms
are probably chiefly due to compression of the subclavian artery by
the rib, though possibly compression of sympathetic fibres in the first
dorsal nerve may play a part. Attacks of blanching or cyanosis of the
fingers sometimes occur and even gangrene has been described. The
radial pulses are frequently unequal, that upon the affected side
possessing a smaller volume than its fellow, but they may become
equal when the hands are held above the head. The course of the
subclavian arteries is frequently abnormal when cervical ribs are
present, and the artery can be felt passing obliquely across the
posterior triangle of the neck from a point $\frac{1}{4}$ to 1 inch above the lower
border of the sternomastoid to a point behind the middle of the
clavicle. Very rarely thrombosis of the subclavian artery has occurred
as a result of the pressure of the rib, and Symonds has reported a case
in which the thrombus extended from the subclavian artery on the
right side into the right common carotid, and a portion, becoming
detached, was carried as an embolus into the right internal carotid.
The cervical rib may be visible or palpable as a bony swelling in the
neck, pressure over which may cause pain or tingling referred to
the ulnar border of the hand and forearm, or obliteration of the radial
pulse   The presence of cervical ribs can be demonstrated radiographi-
cally, but it must be remembered that the symptoms may be due to

a fibrous band, which will not be seen in radiograms, or to a normal first rib.

Diagnosis.

A cervical rib is distinguished from progressive muscular atrophy by the presence of pain and analgesia, and by the absence of muscular fibrillation. In syringomyelia wasting of the small muscles of the hands is associated with analgesia and thermo-anaesthesia, but the sensory loss is usually much more extensive than that associated with a cervical rib, and signs of pyramidal degeneration are likely to be present. Cervical rib is a congenital abnormality which is not uncommonly present in cases of syringomyelia. The radiographic demonstration of the presence of a rib must not, therefore, be taken as proof that the rib is the cause of the patient's symptoms. Lesions of the median and ulnar nerves, especially when they arise from occupational pressure in the palm, may be confused with cervical rib, but the diagnosis is established by the characteristic distribution of the motor and sensory symptoms of lesions of these nerves. For other causes of wasting in the hands see p. 753.

Treatment.

Only surgical treatment affords permanent relief from the symptoms of a cervical rib, and to obtain the best results it should be undertaken early. The precise operation required depends upon the nature of the abnormality present. It may be necessary to remove a cervical rib or a large seventh cervical transverse process, or a portion of the first rib, if that is the offender. Usually it is sufficient to divide the scalenus anticus muscle, thus allowing the first rib to drop. Following operation there is rapid relief of the sensory symptoms and considerable improvement in muscular power may be anticipated. If there is severe muscular atrophy before operation, it is unlikely that full recovery will occur. Hence the importance of operating early. The usual treatment of peripheral nerve lesions must be carried out.

THE POSTERIOR THORACIC NERVE

The posterior thoracic nerve is derived by three roots from the fifth, sixth, and seventh cervical nerves. The upper two roots pass through the scalenus medius muscle. The nerve, which supplies the serratus magnus, is injured alone most frequently as a result of pressure upon the shoulder, either from a sudden blow or from the prolonged pressure of carrying weights on the shoulder. Occasionally it is a site of neuritis, and it may be involved in inflammation secondarily to apical pleurisy. When the lesion is a neuritis there

may be considerable pain in the neck at the onset, and it is possible
that the neuritis is secondary to a fibrositis of the scalenus medius.
Isolated lesions of this nerve are comparatively rare.

The serratus magnus fixes the scapula to the chest wall when for-
ward pressure is exerted with the upper limb. It brings the scapula
forward when the upper limb is thrust forward, as in a fencing lunge,
and it assists in elevating the limb above the head by rotating the
scapula. Paralysis of the serratus magnus causes no deformity of the
scapula when the limb is at rest. If, however, the patient is asked to
push the limb forward against resistance, the inner border of the
scapula becomes winged, especially in its lower two-thirds (Fig. 71).
He is unable to raise the limb above the head in front of him. The
usual treatment of the paralysed muscle is carried out, but recovery
does not always occur. In such cases Sherren recommends trans-
planting the sternocostal portion of the pectoralis major from the
arm to the inferior angle of the scapula.

THE CIRCUMFLEX NERVE

The circumflex nerve arises from the posterior cord of the brachial
plexus. It innervates the teres minor and deltoid muscles and supplies
cutaneous sensibility to an oval area, the long axis of which extends
from the acromion process to half-way down the outer aspect of the
arm (Figs. 4 and 5). Injury to the circumflex nerve, therefore, causes
wasting and paralysis of the deltoid muscle, with paralysis of
abduction of the arm and anaesthesia and analgesia corresponding
to its cutaneous supply. The circumflex nerve may be injured as a
result of surgical lesions in the region of the neck of the humerus
and is sometimes the seat of interstitial neuritis. The arm should be
splinted in a position of abduction at the shoulder, and the usual
treatment for peripheral nerve lesions applied.

THE MUSCULO-SPIRAL NERVE

The musculo-spiral nerve constitutes the termination of the pos-
terior cord of the brachial plexus and is derived from the fifth, sixth,
seventh, and eighth cervical spinal nerves. It innervates the follow-
ing muscles in the order given: triceps, anconeus, supinator longus,
extensor carpi radialis longior, and, through the posterior inter-
osseous nerve, extensor carpi radialis brevior, supinator brevis, ex-
tensor communis digitorum, extensor minimi digiti, extensor carpi
ulnaris, the three extensors of the thumb, and extensor indicis.
It supplies sensibility to the lower half of the radial aspect of the
arm and the middle of the posterior aspect of the forearm. By the
radial nerve it supplies sensation to a variable area on the dorsum

of the hand extending from the wrist distally as far as the inter-phalangeal joint of the thumb and the metacarpo-phalangeal joints of the index and middle fingers, and bounded laterally by the radial

Fig. 71   Winging of the scapula due to paralysis of the left serratus magnus.

border of the thumb, and medially by the axis of the middle meta-carpal (Figs. 4 and 5).

Complete interruption of the musculo-spiral nerve in or above the axilla causes paralysis and wasting of all the muscles it supplies. Para-lysis of the triceps leads to inability to extend the elbow. Paralysis of the supinator longus is detected through failure of this muscle to

contract when the patient flexes the elbow with the forearm midway between pronation and supination, the supinator longus acting as a flexor of the elbow and not as a supinator. Paralysis of the supinator brevis leads to loss of supination. Paralysis of the extensors of the wrist and fingers causes wrist- and finger-drop. Not only is the patient unable to extend the wrist as a primary movement, but synergic extension of the wrist fails to occur in association with flexion of the fingers, with a resulting impairment of the power of this movement. In investigating extension of the thumb special attention must be paid to extension at the carpo-metacarpal and metacarpo-phalangeal joints, since extension at the terminal joint may be carried out by some of the intrinsic muscles of the hand. The long extensors of the fingers produce extension only at the metacarpo-phalangeal joints, extension at the other joints being brought about by the interossei and lumbricals. In a case of musculo-spiral paralysis, when the patient attempts to extend the fingers, the last-named muscles contract synergically and produce flexion at the metacarpo-phalangeal and extension at the interphalangeal joints. Following a lesion of the musculo-spiral nerve sensory loss is variable and may be absent.

When the nerve is injured, as most frequently happens, in the lower third of the arm, the triceps usually escapes paralysis, and the branch to the supinator longus, and less frequently that to the extensor carpi radialis longior, may also escape, the distribution of the paralysis coinciding with that following a lesion of the posterior interosseous nerve. The musculo-spiral nerve is frequently injured where it winds round the humerus as a result of fractures of that bone. It is also liable to compression in the axilla through the use of a crutch, and when the arm of an anaesthetized patient is allowed to hang over the edge of the operating table, and during sleep, especially when the patient is intoxicated. In such cases pressure may be due to the arm hanging over the back of a chair, and I have known musculo-spiral palsy occur in a man who went to sleep on Hampstead Heath on a Bank Holiday with a girl lying on his arm. The nerve is occasionally the site of interstitial neuritis, which may be confined to the posterior interosseous nerve.

Splinting is of great importance in the treatment of musculo-spiral paralysis. A splint must be used to maintain extension of the wrist, but although extension at the metacarpo-phalangeal joints must be ensured, these joints must not be rigidly fixed. A system of elastic extension should, therefore, be used for the fingers. The thumb and finger-tips are covered with the fingers of a leather glove, to which elastic tapes are attached. These are carried back over the dorsum of the hand to be attached to a leather bracelet, which

is fixed to the splint beneath the wrist. The paralysed muscles are treated in the usual way by means of massage and electricity.

The prognosis of lesions of the musculo-spiral nerve is good. Even after suture, signs of returning muscular function are usually evident in from four to eight months, according to the level of the lesion.

The Musculo-cutaneous Nerve

The musculo-cutaneous nerve is a branch of the outer cord of the brachial plexus, its fibres being derived from the fifth and sixth cervical spinal nerves. It supplies the biceps and brachialis anticus, the principal flexors of the elbow, and its sensory distribution is to the radial border of the forearm as low as the carpo-metacarpal joint of the thumb (Figs 4 and 5).

Division of the musculo-cutaneous nerve, therefore, causes weakness of flexion of the elbow-joint, though some power of flexion can still be carried out by the supinator longus and the part of the brachialis anticus which is innervated by the musculo-spiral nerve. Sensation is impaired over the cutaneous distribution of the nerve. The musculo-cutaneous nerve is rarely injured alone, but may be damaged by dislocation of the head of the humerus or by penetrating wounds.

The forearm should be supported in a sling and the paralysed muscles treated with massage and electricity.

The Median Nerve

The fibres of the median nerve are derived from the sixth, seventh, and eighth cervical and first dorsal spinal segments. It is formed by the union of two heads from the inner and outer cords of the brachial plexus. It supplies the following muscles, to which branches are given in the order named pronator radii teres, flexor carpi radialis, palmaris longus, flexor sublimis digitorum, flexor longus pollicis, flexor profundus digitorum, pronator quadratus, the two radial lumbricals, opponens pollicis, abductor brevis pollicis, and the outer head of the flexor brevis pollicis. Sometimes it supplies the first dorsal interosseous.

After a complete lesion of the median nerve above its highest muscular branch there is, therefore, paralysis of pronation of the forearm. The radial flexor of the wrist is paralysed, so that when the wrist is flexed against resistance the hand deviates to the ulnar side. There is inability to flex the terminal phalanx of the thumb and the phalanges of the index finger. There is weakness of flexion of the phalanges of the remaining fingers, especially the middle finger, but not complete paralysis, since the ulnar half of the flexor profundus digitorum is supplied by the ulnar nerve. Flexion at the metacarpo-

phalangeal joints is carried out by the interossei and lumbricals, of which only the two outer lumbricals are innervated by the median nerve. Paralysis of the muscles of the thenar eminence supplied by the median nerve leads to loss of power to abduct the thumb, a movement which must be tested in a plane at right angles to the palm, and opposition of the thumb is lost. Wasting is present in the paralysed muscles and is especially conspicuous in the thenar eminence, where wasting of the abductor pollicis renders the first metacarpal unduly prominent. A lesion of the median nerve in the middle of the forearm may paralyse the superficial flexor of the index finger, while allowing those of the other three fingers, the branches to which leave the nerve at a higher level, to escape. When the nerve is injured at the wrist paralysis is confined to the hand. When investigating muscular power after a median nerve lesion it must be remembered that the extensor ossis metacarpi pollicis may be used in a trick movement as a radial flexor of the wrist and that opposition of the thumb may be simulated by the combined action of the adductors and the extensor ossis metacarpi pollicis.

Sensory loss following a lesion of the median nerve is somewhat variable, especially in regard to the appreciation of pin-prick (Figs. 4 and 5). Loss of this form of sensibility may be confined to the terminal phalanges of the index and middle fingers, the affected area *being somewhat more extensive on their palmar than on their dorsal aspect.* Appreciation of pin-prick may, however, be lost over a somewhat larger area, including the palmar aspect of the terminal phalanx of the thumb. Loss of appreciation of light touch is more *constant in its outline, which runs along the radial border of the thumb to the base of the thenar eminence, thence across the palm to* the cleft between the middle and ring fingers, and includes approximately half of the palmar aspect of the ring finger on the radial side. *On the dorsum it includes the radial aspect of the terminal two-thirds* of the ring finger and the dorsal aspect of the middle and index fingers as far proximally as the middle of the proximal phalanges. From the radial side of the index finger the border passes along the fold of the first interosseous space and up the inner border of the thumb *as far as* the ulnar edge of the nail. Deep sensibility is usually lost in the terminal phalanges of the index and middle fingers. The median nerve is the commonest site of causalgia, which only occurs, however, when the lesion is incomplete.

The median nerve may be injured at any point of its course by stab or gun-shot wounds. It is occasionally damaged in dislocation of the shoulder. The commonest lesion in civil life is a cut at the wrist, usually the result of the hand having been put through a window. In such cases the ulnar nerve may also be damaged. The median is

rarely the site of interstitial neuritis. When this occurs it is usually secondary to arthritis of the wrist. The nerve may also be damaged at the wrist by prolonged occupational pressure. This form of median palsy is sometimes seen in gardeners, from pressure of the handle of a trowel; in scrubbers, from the pressure of a scrubbing-brush; and in tailors, from the use of heavy shears.

No splint is required. The usual treatment for the paralysed muscles is carried out. Causalgia requires special treatment, see p. 738. Signs of returning sensibility usually precede motor recovery. After suture of the nerve the latter occurs in from three months to a year, depending upon the situation of the lesion and the distance of individual muscles below it. Voluntary power usually reappears first in pronator radii teres and in flexor carpi radialis. Sensory recovery is frequently incomplete, especially in respect of appreciation of light touch upon the index finger.

THE ULNAR NERVE

The ulnar nerve is derived from the eighth cervical and first dorsal spinal nerves. It gives off no branches above the elbow, where it lies behind the internal condyle of the humerus. It supplies branches to the following muscles in the forearm in the order stated: flexor carpi ulnaris and the inner half of flexor profundus digitorum. In the hand it supplies the palmaris brevis, the muscles of the hypothenar eminence, the two inner lumbricals, the palmar and dorsal interossei, the adductors transversus and obliquus pollicis, and the inner head of the flexor brevis pollicis. The first dorsal interosseous muscle is sometimes supplied by the median.

Interruption of the ulnar nerve at or above the level of the elbow causes paralysis of these muscles. As a result of paralysis of the flexor carpi ulnaris the hand deviates to the radial side on flexion of the wrist against resistance. Another method of demonstrating weakness of this muscle is as follows: the patient closes his hand and the examiner adducts it, placing his finger on the tendon of the flexor carpi ulnaris. When the patient extends his fingers this tendon can normally be felt to tighten. Paralysis of the ulnar half of the flexor profundus digitorum abolishes flexion of the little finger at the interphalangeal joints, and weakens flexion of the ring finger at these joints. Paralysis of the muscles of the hypothenar eminence abolishes abduction of the little finger and impairs flexion of this finger at the metacarpo-phalangeal joint. Paralysis of the interossei abolishes abduction and adduction of the fingers. In examining this movement it is important that the hand should be kept with the palm pressed against a flat surface, as the long extensors and flexors of the fingers act to some extent as abductors and adductors. Paralysis of the

adductors transversus and obliquus pollicis weakens adduction of the thumb, and this is most evident when the patient attempts to press the thumb firmly against the index finger.

Wasting of the paralysed muscles is evident on the ulnar side of the flexor aspect of the forearm, the hypothenar eminence, the interosseous spaces, and the ulnar half of the thenar eminence. Paralysis of the small muscles of the hand causes 'claw-hand', this posture being produced by the unopposed action of their antagonists. Since the interossei cause flexion of the fingers at the metacarpo-phalangeal joints and extension at the interphalangeal joints, when these muscles are paralysed the opposite posture is maintained by the long flexors and extensors, namely, hyperextension at the metacarpo-phalangeal joints and flexion at the interphalangeal joints. *This is usually most* marked in the ring and little fingers, since the two radial lumbricals which are supplied by the median nerve to some extent compensate for loss of action of the interossei on the index and middle fingers.

After a lesion of the ulnar nerve at or above the elbow, loss of deep sensibility is usually limited to the little finger. The area of analgesia to pin-prick is variable, but usually covers the little finger and the ulnar border of the palm. The area of anaesthesia to light touch includes the little finger and the ulnar half of the ring finger, together with *the ulnar border of the hand, both on the dorsum and the palmar* aspects as far as the wrist, the area being bounded on the radial side *by a line continuous with the axis of the ring finger (Figs. 4 and 5).*

When the ulnar nerve is divided at the wrist the flexor carpi ulnaris and the ulnar half of the flexor profundus digitorum escape paralysis, which is confined to the small muscles of the hand supplied by the nerve. When the lesion is below the point at which the dorsal branch is given off, the area of sensory loss is less than that described above. On the palmar aspect of the hand the area over which sensibility is lost is the same as when the nerve is divided above the wrist, but on the dorsal aspect appreciation of light touch is lost *over the terminal two phalanges of the little finger and the ulnar half* of these phalanges of the ring finger, and loss of appreciation of pin-prick *is usually confined to the terminal phalanx of the little finger.*

Lesions of the ulnar nerve above the elbow are rare, but it may be involved in a penetrating wound. At the elbow it may suffer as a result of fractures and dislocations involving the lower end of the humerus and the elbow-joint. In such cases the injury to the nerve may be immediate. *Occasionally, however, it is involved years after* an injury which has led to cubitus valgus. Similarly the nerve may be damaged by osteophytic outgrowths following arthritis of the elbow-joint, and such a lesion may be bilateral. I have known it compressed by a Charcot elbow.

In individuals possessing a shallow groove for the nerve behind the internal condyle of the humerus or an unusual degree of physiological cubitus valgus, the nerve may suffer from undue mobility, tending to slip forwards over the internal condyle when the elbow is flexed. Occupations involving repeated flexion of the elbow occasionally cause symptoms through the long-continued minor trauma involved. In all these cases of chronic injury of the nerve at the elbow-joint the lesion is a localized pressure neuritis associated with fibrous thickening of the nerve at the site of trauma, where a spindle-shaped swelling can often be felt. The earliest symptoms are pain and paraesthesiae referred to the cutaneous distribution of the nerve, and as the full, and not the exclusive, supply of the nerve is involved, the area to which the symptoms are referred extends farther, especially on the radial side of the palm, than the area over which cutaneous sensibility is impaired after the nerve is divided. This symptom may at first be apparent only when the patient awakens in the morning after sleeping with the elbow flexed. In long-standing cases there are usually weakness and wasting of the muscles innervated by the nerve. Ulnar paralysis is occasionally met with as a result of pressure on the nerve at the elbow during sleep. At the wrist the ulnar nerve may be injured by cuts and the median nerve may be simultaneously involved. A pressure neuritis of the deep palmar branch of the ulnar nerve sometimes occurs in individuals whose occupation involves prolonged pressure upon the outer part of the palm. In such cases the muscles of the hypothenar eminence usually escape damage and there is no sensory loss. Apart from traumatic lesions the ulnar nerve is rarely the site of interstitial neuritis.

The treatment of lesions of the ulnar nerve is conducted on the same general lines as for other peripheral nerve lesions. No splint is required. When the nerve is the site of pressure neuritis as a result of abnormalities of the elbow-joint, an appropriate operation will be required to free the nerve from pressure. When the nerve suffers from repeated dislocation it must be brought in front of the internal condyle of the humerus. In such cases operation rapidly relieves sensory symptoms, but recovery of voluntary power is necessarily slower. After suture of the nerve sensibility usually begins to recover *before voluntary power. Motor recovery usually begins in the flexor carpi ulnaris and flexor profundus digitorum,* and is least complete in these muscles and in the abductor minimi digiti. It may take 2 years after primary suture at the elbow.

Diagnosis of Wasting of the Muscles of the Hand.

Lesions of the median and ulnar nerves require to be diagnosed from other causes of wasting of muscles of the hand. These muscles

are innervated by the anterior horn cells of the first dorsal segment of the spinal cord. The causes of their wasting, therefore, include lesions of their lower motor neurones at any point between this spinal segment and the muscles, together with certain other conditions in which primary muscular degeneration or reflex muscular wasting occur.

Lesions of acute onset involving the Anterior Horns.

The commonest of such acute lesions is *acute anterior poliomyelitis*. This is usually easily distinguished by the acute onset, commonly in childhood, the non-progressive character of the wasting, the presence of muscular wasting with a patchy and asymmetrical distribution elsewhere in the body, the cyanosis of the affected extremity, and the absence of sensory loss. *Vascular lesions of the spinal cord* are rare. Syphilitic thrombosis of a branch of the anterior spinal artery may cause destruction of the anterior horn cells. In such cases the spino-thalamic tract is usually simultaneously damaged. Serological tests establish the cause of the lesion. *Haematomyelia* may destroy the anterior horn cells of the cervical enlargement. There is sometimes a history of traumatic extension of the cervical spine. Wasting is not confined to muscles innervated by the first dorsal segment and is usually associated with extensive sensory loss over the upper limbs and often with involvement of the long ascending and descending tracts of the cord.

Lesions of slow onset involving the Anterior Horns.

The commonest chronic lesion is *progressive muscular atrophy*, which frequently begins with wasting of the small muscles of one or both hands. This condition is distinguished by its progressive course, the presence of muscular fibrillation and, sooner or later, wasting of other muscle groups, the frequent coexistence of pyramidal degeneration, and the absence of sensory loss. In *syringomyelia* wasting of the hand muscles is often an early symptom. Fibrillation is usually absent. The diagnosis depends upon the characteristic associated analgesia and thermo-anaesthesia, trophic lesions, and the frequent involvement of the pyramidal tracts. In *tumour of the spinal cord* the signs of a progressive focal lesion at the cervical enlargement are sooner or later associated with those of spinal subarachnoid block.

Lesions of the Anterior Roots.

The anterior roots are occasionally involved in the localized *leptomeningitis of syphilitic origin*, in which the substance of the cord usually also suffers. The anterior root lesion can be distinguished from a lesion of the anterior horn cells only when the posterior roots are also involved, leading to root pains, often with some impairment of sensibility over the segmental cutaneous areas.

Lesions of the Spinal Nerve.

The spinal nerve consists of a fusion of both the anterior and the posterior root, and a lesion of the first dorsal nerve, therefore, causes root pain and frequently some sensory loss along the ulnar border of the hand and forearm in addition to muscular wasting of the small muscles of the hand. The spinal nerve may be the site of *neuritis*, though this is rare in the case of the first dorsal nerve. It may be compressed as a result of collapse or inflammatory hyperostosis of the vertebral column. A traumatic lesion of the first dorsal spinal nerve is responsible for the *Klumpke type of birth palsy*. Lesions involving the first dorsal segment of the spinal cord, its anterior roots and spinal nerves, usually cause paralysis of the cervical sympathetic, the preganglionic fibres of which leave the cord at this level.

Lesions of the Inner Cord of the Brachial Plexus.

Lesions of the inner cord of the plexus, for example, the pressure of a *cervical rib*, cause wasting of all the muscles supplied by the ulnar nerve, including those in the forearm together with the small muscles of the hand supplied by the median The distribution of pain and sensory loss involves the eighth cervical and first dorsal segmental areas, that is, roughly, the supply of the ulnar nerve, together with the distal half or two-thirds of the ulnar border of the forearm.

Lesions of the Median and Ulnar Nerves

All lesions situated between the anterior horn cells of the first dorsal segment and the inner cord of the brachial plexus, inclusive, cause wasting of all the small muscles of the hand. Distally to the inner cord of the plexus the innervation of these muscles is divided between the ulnar and median nerves Lesions of these nerves, as has already been described, are distinguished by the characteristic distribution of the muscular wasting and sensory loss. Apart from localized lesions of these nerves, wasting of the small muscles of the hand may occur in various forms of *toxic polyneuritis* and *progressive hypertrophic polyneuritis*, conditions in which sensory loss of peripheral distribution and tenderness of the muscles are usually present, and the same symptoms frequently occur in the lower limbs. In *peroneal muscular atrophy* wasting of the hands usually follows that of the feet. The onset of the wasting in early life, its gradual ascent of the limbs, and the associated peripheral sensory loss are distinguishing features.

Muscular Dystrophy.

Wasting of the small muscles of the hand is found in some forms of *muscular dystrophy*, especially the so-called distal type of myopathy and in *myotonia atrophica*. The diagnosis depends upon the age of onset, the symmetrical character, distribution, and progressive course of the wasting, the absence of muscular fibrillation, sensory loss and signs of involvement of the central nervous system, and the familial or hereditary nature of the disorder.

Trophic Disorders.

Reflex muscular wasting secondary to *arthritis* of the joints of the hand must not be overlooked. It is easily recognized on account of pain, swelling, and bony changes in the joints. *Ischaemia* due to arteriosclerosis or thrombo-angeitis is a rare cause of muscular wasting, more frequently seen in the lower than in the upper limb. *Ischaemic myositis* (ischaemic contracture) caused by the pressure of a splint too tightly applied to the forearm leads to paralysis, wasting and contracture of the muscles of the forearm and hand, with or without sensory loss due to compression and degeneration of the nerves.

INTERNAL CUTANEOUS NERVE

The internal cutaneous nerve is a purely sensory nerve derived from the inner cord of the brachial plexus and receiving fibres from the first dorsal spinal nerve. It supplies cutaneous sensibility to the ulnar border of the forearm and the proximal part of the ulnar border of the hand (Figs. 4 and 5). It is rarely damaged alone and most frequently suffers from compression of the inner cord of the plexus by a cervical rib.

TOURNIQUET PARALYSIS

The application of a tourniquet to the upper limb is sometimes followed by paralysis below the site of compression. The application of a tourniquet is usually for the purpose of operations, for example, on the fingers. It is probable that in addition to the actual compression of the nerves, deprivation of their blood-supply is an important factor in causing paralysis. Paralysis attended by wasting is confined to the muscles below the site of compression and is usually associated with impairment of all forms of sensibility, *cutaneous anaesthesia and analgesia being limited above by a sharp upper border corresponding to the site of compression.* The usual treatment of a peripheral nerve lesion must be carried out. Recovery is usually ultimately complete.

THE NERVES OF THE LOWER LIMB

THE LUMBO-SACRAL PLEXUS

The lumbar plexus is formed by contributions from the twelfth dorsal and the first, second, third, and fourth lumbar spinal nerves; the sacral plexus, from the fourth and fifth lumbar and the first, second, and third sacral nerves. The principal nerves derived from the lumbar plexus are the anterior crural and the obturator, and from the sacral plexus the sciatic and the superior and inferior gluteal nerves. The lumbo-sacral plexus may be compressed by neoplastic metastases or may be the site of interstitial neuritis. The symptoms of this are described in the sections dealing with individual nerves. The plexus may be injured by the pressure of the foetal head during delivery; either the obturator or the sciatic nerves may be thus damaged on one or both sides. The lumbo-sacral cord is most frequently affected, leading to unilateral or bilateral paralysis of the anterior tibial and peroneal muscles. (See also under Lesions of the Sciatic Nerve, pp. 759–62.)

THE EXTERNAL CUTANEOUS NERVE

The external cutaneous nerve is derived from the posterior parts of the second and third lumbar nerves. Passing through the psoas major muscle it enters the thigh beneath the lateral end of Poupart's ligament, and, piercing the fascia lata of the thigh about 4 inches distal to the anterior superior iliac spine, it divides into an anterior and a posterior branch which supply sensibility to the lateral aspect of the thigh and the lateral part of its anterior aspect from the buttock almost as low as the knee (Figs 4 and 5). As the nerve passes through the fascia lata it may become constricted by fibrous tissue with the production of pain, numbness, and paraesthesiae referred to the cutaneous distribution of the nerve, especially of its anterior branch. This condition, which is known as 'meralgia paraesthetica' usually afflicts middle-aged men. The pain and numbness are brought on by walking, which may suggest arterial disease. The site of the pain, which is usually associated with relative analgesia of the skin of the outer aspect of the thigh is distinctive. The disorder usually requires operation, the channel in the fascia lata being enlarged if necessary as high as Poupart's ligament.

THE OBTURATOR NERVE

The obturator nerve is derived from the second, third, and fourth lumbar nerves by roots which are situated anteriorly to those of the anterior crural nerve. The union of these roots occurs in the psoas

muscle and the nerve emerges from the pelvis by the obturator foramen. It gives a branch to the hip joint and supplies the following muscles: adductor longus and gracilis, adductor brevis usually, and sometimes pectineus, obturator externus, and adductor magnus. Its cutaneous supply is variable and is distributed to the skin of the distal two-thirds of the medial aspect of the thigh (Figs. 4 and 5). It also supplies a branch to the knee-joint.

Injury to the obturator nerve causes paralysis of the adductors of the thigh, except for the flexor fibres of the adductor magnus, which are innervated by the sciatic. Sensory loss is usually absent. The nerve is most frequently injured in the course of a difficult labour, occasionally as a result of dislocation of the hip or obturator hernia.

No splint is required. The usual treatment of lower motor neurone paralysis is applied to the paralysed muscles.

THE ANTERIOR CRURAL NERVE

The anterior crural nerve is derived from the lumbar plexus, arising from the posterior parts of the second, third, and fourth lumbar nerves, posterior to the obturator nerve. The nerve is formed in the psoas major muscle, and after passing through the pelvis enters the thigh beneath Poupart's ligament, lateral to the femoral sheath and femoral vessels. In the abdomen it sends a branch to the iliacus muscle and in the femoral triangle it breaks up into terminal branches which supply the pectineus, sartorius, and quadriceps. It gives articular branches to the hip- and knee-joints. Its middle and internal cutaneous branches supply the medial and internal aspects of the thigh in its lower two-thirds, and by the long saphenous nerve it supplies sensibility to the inner aspect of the leg and foot as far distally as midway between the internal malleolus and the base of the great toe (Figs. 4 and 5).

After a lesion of the anterior crural nerve there may be slight weakness of flexion of the hip owing to paralysis of the iliacus, but the principal motor disturbance is weakness of extension of the knee owing to paralysis of the quadriceps, which is wasted. As a result of this the leg gives way in walking and cannot be used to raise the body on stairs. The knee-jerk is lost, and sensibility is lost over the cutaneous area innervated by the nerve. Causalgia may occur in the distribution of the long saphenous branch after partial lesions of the nerve.

The commonest lesion of the anterior crural nerve is interstitial neuritis It may be involved in psoas abscess or in new growths within the pelvis, or injured as a result of fractures of the pelvis or of the femur, or by dislocation of the hip. Lesions of the anterior crural nerve are rarely seen as a result of gun-shot wounds of the

thigh, as the proximity of the femoral artery renders the majority of such injuries rapidly fatal.

No splint is required in the treatment of lesions of the anterior crural nerve. Support to the leg may be given by means of a strong elastic band running from a belt over the front of the thigh to be attached to a gaiter round the calf. The usual treatment of lower motor neurone paralysis should be applied to the quadriceps For the diagnosis, symptoms, and treatment of anterior crural neuritis see p. 769.

The Sciatic Nerve

The sciatic nerve is derived from the sacral plexus, which is formed by a fusion of the anterior primary divisions of the fourth and fifth lumbar and of the first, second, and third sacral spinal nerves. The nerve is composed of two divisions which are destined to form the internal and external popliteal nerves. These two divisions, though bound together by connective tissue, are separable up to the sacral plexus from which they are separately derived, the internal popliteal coming from the anterior trunks of the fourth and fifth lumbar and first and second sacral nerves, while the external popliteal comes from the posterior trunks of the fourth and fifth lumbar and first, second, and third sacral nerves The sciatic nerve, in addition to its two principal components, contains nerves to the hamstrings and a nerve to the short head of the biceps muscle It leaves the pelvis by passing through the great sciatic notch below the piriformis muscle into the buttock and then descends in the back of the thigh, lying between the great trochanter of the femur and the tuberosity of the ischium. It terminates at a variable point between the sciatic notch and the proximal part of the popliteal fossa by dividing into the external and internal popliteal nerves.

In addition to supplying motor nerves to the semitendinosus, semimembranosus, the long head of the biceps, the short head of the biceps, and adductor magnus, the sciatic is the motor nerve to all the muscles below the knee. The musculo-cutaneous branch of the external popliteal nerve supplies the peronei longus and brevis, the anterior tibial branch supplies the tibialis anticus, extensor longus digitorum, extensor longus hallucis, peroneus tertius, and extensor brevis digitorum. The internal popliteal nerve supplies muscular branches in the following order: gastrocnemius, popliteus, plantaris, and soleus, and the posterior tibial nerve innervates the popliteus, the deep part of the soleus, tibialis posticus, flexor longus digitorum, and flexor longus hallucis. The internal and external plantar nerves supply the small muscles of the feet.

After complete interruption of the sciatic nerve there is

paralysis of flexion of the knee, which is carried out by the hamstrings, and of all the muscles below the knee. Foot-drop occurs as a result of paralysis of the anterior tibial group of muscles and of the peronei. The patient is able to stand and to walk, but drags the toes of the affected foot and is unable to stand on his toes on the paralysed side.

The sensory distribution of the sciatic nerve lies entirely below the knee (Figs 4 and 5). After complete division of the nerve light touch is the form of sensibility which is most extensively lost. Anaesthesia to cotton-wool extends over the whole of the foot, with the exception of a zone about 1½ inches wide along the inner aspect, extending about 2 inches distal to the internal malleolus, this area being supplied by the long saphenous nerve. On the leg the area of anaesthesia to light touch includes the outer aspect, roughly from the middle line in front to the middle line behind as far up as 2 inches below the upper end of the fibula. Analgesia to pin-prick is less extensive than anaesthesia to light touch. Below, the two areas approximately coincide, but above, the area of analgesia is less extensive than that of anaesthesia by 2 or 3 inches. Appreciation of pressure and of vibration is lost over the whole of the foot, with the exception of the proximal two-thirds of the inner aspect, and postural sensibility and appreciation of passive movement are lost in the toes.

The knee-jerk is unaffected, but the ankle-jerk is lost and so also is the plantar reflex. Vasomotor and trophic changes are usually conspicuous after complete division of the sciatic. The leg is congested and swollen, especially when it is allowed to hang down. The skin is dry, and sweating is lost over the foot, except along the inner border, where it is supplied by the long saphenous nerve. Perforating ulcers may develop on the sole.

The sciatic nerve may be damaged as a result of fractures of the pelvis and femur and gun-shot wounds of the buttock and thigh. It may be compressed within the pelvis by neoplasms, or by the foetal head during delivery. The external popliteal division is much more susceptible to injury than the internal popliteal. Complete division of the whole nerve is rare.

The differential diagnosis of lesions of the sciatic nerve is discussed in the section dealing with sciatic neuritis.

THE EXTERNAL POPLITEAL NERVE

After division of the external popliteal nerve there is paralysis with wasting of the peronei and of the anterior tibial group of muscles. The power of dorsiflexion of the foot and toes and of eversion of the foot is lost, and foot-drop results. Inversion is lost when the foot is dorsiflexed, but a weak movement of inversion is possible in association with plantar flexion. When the nerve is divided above

the point of origin of its lateral cutaneous branch, sensation is impaired over the dorsum of the foot, including the first phalanges of the toes, and over the antero-external aspect of the leg in its lower half or two-thirds, the area of anaesthesia to light touch being somewhat more extensive than the area of anaesthesia to pin-prick (Figs. 4 and 5). When the lesion is situated below the origin of the lateral cutaneous branch, sensation is impaired over the dorsum of the foot only, and the anaesthetic area is usually bounded by a line passing upwards from the space between the fourth and fifth toes parallel with the outer border of the foot. Deep sensibility is *unimpaired.*

The external popliteal nerve may be injured as a result of penetrating wounds in the neighbourhood of the knee-joint and of fractures involving the upper end of the fibula. It is sometimes the *site of interstitial neuritis and may suffer from compression by a tight* bandage applied to the knee or pressure during sleep. In the case of neuritis and compression of the nerve the muscles which it innervates do not always suffer equally. The peronei are usually more gravely *affected than the anterior tibial group, and the area of* sensory loss is often less than that found after complete division of the nerve.

THE INTERNAL POPLITEAL NERVE

After division of the internal popliteal nerve the calf muscles and the muscles of the sole are paralysed and wasted and the foot assumes the position of talipes calcaneo-valgus. The ankle-jerk is lost, and the plantar reflex may also be unelicitable. There is as a rule no loss of deep sensibility. There is anaesthesia to light touch over the skin of the sole, including the plantar aspect of the toes and the dorsal aspect of their terminal phalanges. The area of analgesia to prick is less extensive and does not include the toes (Figs. 4 and 5).

Treatment of Lesions of the Sciatic Nerve.

After lesions of the sciatic nerve and of the external popliteal nerve it is important to prevent dropping of the foot. The patient should, therefore, wear an aluminium night-shoe at night, and during the day the foot drop must be overcome by wearing a boot with a toe-raising spring. The usual treatment of peripheral nerve lesions should be carried out, including massage and electricity. Recovery is always slow after complete division of the nerve. When the sciatic nerve-trunk has been divided return of voluntary power cannot be expected for from a year to eighteen months, and may take much longer. It may be necessary to carry out treatment for three years. In the case of division of the external popliteal nerve return of power

may be expected to be demonstrable in from nine months to a year, but it is likely to be at least two years before the maximum degree of recovery is attained.

COCCYGODYNIA

'Coccygodynia' is the term applied to a painful affection which occurs almost exclusively in the female sex and which is characterized by neuralgic pain situated in the coccyx and lower part of the sacrum and in severe cases radiating into the buttocks and down the posterior aspect of the thighs. The pain usually develops after an injury, especially a fall in the sitting position, and sometimes after childbirth.

The pathology of coccygodynia is obscure. Although at the onset it probably possesses an organic basis, the majority of sufferers are highly neurotic, and neurosis plays an important part in its perpetuation. The disorder when well established is very refractory to treatment, which, therefore, should be begun as early as possible. The patient's general health should be maintained at a high level, and sedatives will probably be required. Two methods of local treatment are often of value—diathermy, one electrode being placed in the rectum and the other over the sacrum, and sacral epidural injection with novocain and saline by the method used in the treatment of sciatic neuritis (see p. 774). X-ray irradiation of the sacro-coccygeal region may also be tried. Alcoholic injection is inadvisable and surgical excision of the coccyx is unlikely to give relief and may help to perpetuate the symptom.

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5. INTERSTITIAL NEURITIS

Definition: An inflammation of the connective tissue of a peripheral nerve, causing pain and impairment of the functions of the nerve as a result of compression of the nerve fibres, at first by inflammatory exudate and later by overgrowth of connective tissue

The term 'neuralgia' has been vaguely used to describe many conditions associated with pain within the distribution of a peripheral nerve. Apart from trigeminal neuralgia, the cause of which is obscure, neuralgia possesses no constant clinical or pathological connotation.

Pathology.

Macroscopically the peripheral nerve, which is the site of interstitial neuritis, is swollen and hyperaemic. At first it may be softer than normal. Later it becomes toughened through fibrous overgrowth. Microscopically, in the early stages there is an infiltration of the perineurial and endoneural sheaths with round cells, proliferation of fibroblasts, and congestion of the blood-vessels, with inflammatory infiltration of their walls. Later the signs of active inflammation are replaced by connective-tissue overgrowth, which leads to compression of the nerve-fibres and some degeneration of their medullary sheaths. Interstitial neuritis may occur in a spinal nerve as it passes through its intervertebral foramen, in a plexus, such as the brachial plexus, or in a peripheral nerve. Usually the site of inflammation is single; occasionally multiple nerves are involved.

Aetiology.

Little is known about the aetiology of interstitial neuritis In most cases it appears to be closely related to myositis and fibrositis, and may be regarded as a fibrositis of a peripheral nerve. As a rule the infective organism probably reaches the nerve through the blood-stream from a focus of infection in the teeth, nasal sinuses, tonsils, or prostate. Occasionally interstitial neuritis occurs as a complication of a septicaemic state. Sometimes the nerve is invaded by infection

from an adjacent structure, for example, brachial neuritis may be secondary to arthritis of the cervical spine or shoulder, and sciatic neuritis to arthritis of the lumbar spine or hip. A neurotropic virus is sometimes responsible. Herpes zoster is a form of neuritis, and the virus of herpes simplex may invade a peripheral nerve from the skin lesion, the neuralgic herpes of Mauriac. Interstitial neuritis may be due to other ascending infections from the skin, for example, following a scald or burn. Metabolic abnormalities occasionally play a part in aetiology. Gout holds a time-honoured place, probably with little justification, as a cause of neuritis, and diabetes is sometimes the cause. Sciatic neuritis is sometimes associated with congenital abnormalities of the lumbo-sacral spine. Radium and electric shock are rare causes. Trauma sometimes plays a part in aetiology. Sciatic neuritis is not uncommon in car-drivers. Exposure to cold sometimes precipitates an attack. In some families there appears to be an inherited tendency to fibrositis and neuritis.

NEURITIS OF THE FACE AND SCALP

Neuritis frequently attacks the cutaneous nerves of the face and scalp. Occasionally all the branches of one trigeminal nerve are involved. More frequently the affection is limited to one branch, usually the supra-orbital or auriculo-temporal, less often the infra-orbital. The great occipital nerve is also a common site of neuritis.

Symptoms.

The onset is usually acute, and neuritis of the face and scalp not uncommonly follows a cold, tonsillitis, or an attack of influenza. The patient complains of pain situated within the distribution of *the affected nerve. The pain usually occurs in paroxysms lasting* for several hours, most frequently towards the close of the day, when he is fatigued. An attack of pain is also readily precipitated by exposure to cold. When the pain is severe it interferes with sleep. It is of a dull, aching character, intensified by *exacerbations in which* it is described as shooting along the course of the nerve. There is often hyperalgesia of the area of skin supplied by the nerve, and when this includes the scalp it is noticed on combing and brushing the hair. The nerve-trunk is tender on pressure, which causes irradiation of pain throughout the nerve. The cutaneous hypersensitiveness is readily demonstrated by pricking with a pin.

Diagnosis.

There are numerous causes of paroxysmal pain in the face and scalp, and careful investigation is required to exclude other conditions before falling back on a diagnosis of neuritis.

Infection of the nasal air sinuses is a common cause of such pain, frontal sinusitis being associated with supra-orbital neuralgia and infection of the maxillary antrum with pain in the distribution of the infra-orbital nerve. In ethmoiditis the pain is chiefly at the root of the nose, and in infection of the sphenoidal sinus is usually referred to the forehead or occiput. In acute cases of sinus infection there is usually a history of influenza or a cold in the head with or without a purulent nasal discharge. There may be visible oedema over the frontal sinus or antrum. Transillumination and examination of the nose will usually reveal the site of infection, and in doubtful cases the sinuses should be X-rayed.

The tympanic membranes should always be examined to exclude a latent otitis media.

The teeth are a common cause of facial pain. Search should be made for carious teeth, and the possibility that there is an unerupted tooth must always be considered. This may be present, as may also a buried root, in an apparently edentulous patient, and can only be detected by X-ray examination of the jaws.

A careful examination of the pharynx should be made for a growth, which may occasionally cause pain referred to the ear and neck.

The eye is occasionally the source of referred neuralgic pain, the commonest ocular cause being glaucoma, which may be missed unless this possibility is borne in mind. Pain may also be referred to the face in disease of the heart and lungs.

Intractable neuralgia may follow herpes zoster involving the first division of the trigeminal nerve. The history of the eruption and the residual scars render the diagnosis easy.

Trigeminal neuralgia, tic douloureux, is distinguished by the brevity of the attacks of pain and the characteristic precipitating factors.

In migraine the paroxysms of headache occur at comparatively long intervals and are often associated with vomiting and preceded by the characteristic prodromal symptoms. There is usually a long history.

Tabes is an occasional cause of paroxysmal pain in the face or scalp, but is readily recognized by its other clinical features.

The various intracranial causes of pain in the face and head must be borne in mind, especially lesions of the trigeminal fibres in the brain-stem such as syringobulbia and thrombosis of the posterior inferior cerebellar artery, in both of which pain is usually associated with analgesia and thermo-anaesthesia.

Occipital pain may be due to lesions of the cervical region of the spinal cord or of the vertebral column at this level, especially cervical spondylitis, and is sometimes the result of fibrositis of the cervical muscles.

Hysterical pain, 'psychalgia', is distinguished from neuritis by its lack of relation to a nerve-trunk, its failure to respond to analgesic drugs, and by the patient's exaggerated emotional reaction to the pain.

Prognosis.

In most cases the prognosis of neuritis of the face and scalp is good and there is a rapid response to treatment. Occasionally, however, especially in individuals of a neurotic temperament, the pain proves intractable.

Treatment.

The patient should be kept at rest in a warm room and the affected part protected from cold with a pad of cotton-wool. Counter-irritants are useful, especially in the early stages. One of the proprietary preparations containing methyl salicylate or capsicum may be used, but it is difficult to improve on a mustard leaf, which should be soaked for a minute in warm water and applied over the nerve-trunk for a quarter of an hour on alternate days. Analgesic drugs will be required, and those recommended in the treatment of trigeminal neuralgia (see p. 158) may be used.

Careful search should be made for any septic focus which may be the source of infection of the nerve, and this, if found, should receive appropriate treatment.

If relief of pain does not occur in a few days the affected nerve may be treated with X-ray irradiation. If this fails, it is advisable to inject the nerve-trunk with 2 per cent. novocain solution, the supra-orbital nerve being injected at the supra-orbital notch, the infra-orbital at its foramen, by the methods described in the section on trigeminal neuralgia. The great occipital nerve can be similarly injected, and when occipital pain is due to fibrositis of the cervical muscles relief may sometimes be obtained from novocain injection of any tender spots in the muscles. It is rarely necessary to inject alcohol.

SPINAL NEURITIS

Interstitial neuritis may involve a spinal nerve as it passes through its intervertebral foramen, leading to spinal neuritis or, as it is sometimes less accurately called, spinal radiculitis. The fifth cervical nerve is affected much more frequently than any other, and the sixth cervical appears to suffer next in frequency. Affection of other spinal nerves is rare, unless we include in this group certain forms of sciatic neuritis which are described below. The onset of spinal neuritis is usually acute and is attended by considerable pain referred to the

cutaneous distribution of the affected spinal nerve. The corresponding muscles rapidly become weak or even completely paralysed and *soon exhibit wasting. In neuritis of the fifth cervical nerve the* affected muscles are the rhomboids, spinati, deltoid, biceps, and supinator longus. Objective sensory changes are inconstant, but there is usually at first hyperalgesia, and later a variable area of analgesia overlying the deltoid. Analgesics will be required at first until pain passes off. The upper limb must be splinted with the shoulder abducted to a right angle, the elbow similarly flexed. The usual treatment required in the case of a peripheral nerve lesion must be applied to the paralysed muscles. Recovery of voluntary *power is slow and often incomplete.*

BRACHIAL NEURITIS

Symptoms.

The onset of brachial neuritis is usually subacute. Pain at first is often localized to the neck and supraclavicular region. In the course of a day or two it spreads down the arm into the fingers. It *is increased by moving the limb and is associated with numbness* or hyperæsthesia of a similar distribution, and weakness. There is usually a constant aching pain with paroxysmal exacerbations lasting for several hours and in severe cases interfering with sleep.

The patient keeps the arm flexed and avoids unnecessary movements, though he may from time to time change its posture in an attempt to obtain relief. The brachial plexus and the nerves derived from it are tender on pressure, and stretching the plexus by abducting the shoulder is painful. All the muscles of the limb are weak and their tendon reflexes, which at first may be slightly increased, soon become diminished or abolished. In long-standing cases there is usually slight muscular wasting, but this is rarely severe. Sensation is often slightly impaired over the hand and fingers, light touch and pin-prick yielding a numb feeling. Periarticular adhesions may occur, especially in the shoulder- and finger-joints, in severe cases, and the fingers may be swollen and glossy.

Diagnosis.

Brachial neuritis must be distinguished from compression of the cervical posterior roots by spinal tumour and of the brachial plexus by neoplastic deposits. The onset of compression, however, is more gradual than that of neuritis. The nerve-trunks are not tender on pressure, and weakness, muscular wasting, and sensory loss are pro-*gressive and ultimately much more severe than in neuritis.*

In cervical rib, pain is referred to the ulnar border of the hand

and forearm; there is frequently wasting of the muscles of the hand and an abnormal rib can often be demonstrated radiographically.

Arthritis of the shoulder may be confused with brachial neuritis, but in arthritis the pain and tenderness are localized to the shoulder-joint and the region of the insertion of the deltoid muscle. Pain is evoked by moving the joint, the movements of which are limited, whereas in brachial neuritis rotation of the shoulder can be carried out without pain, provided the plexus is not stretched by abducting the arm. Both conditions may coexist, brachial neuritis being then usually secondary to arthritis of the shoulder. When pain is referred to the upper limb from fibrositis of muscles of the shoulder girdle tender spots can usually be demonstrated in these.

In elderly individuals, occlusion of the brachial artery due to atheroma may simulate brachial neuritis, but this condition is easily distinguished by the reduction or obliteration of the radial pulse on the affected side.

Prognosis.

Brachial neuritis almost always yields satisfactorily to adequate treatment, and there is generally marked improvement in the course of six weeks. Recurrence is uncommon.

Treatment.

Rest is of fundamental importance. The arm should be supported in a sling, and in severe cases the patient should be kept in bed. The limb should be kept warm by wrapping it in cotton-wool, but active heat usually intensifies the pain. Counter-irritants may be applied over the plexus. Analgesic drugs will be required in the early stages, and in severe cases it may be necessary to give morphine. Iodide and salicylate should be given and may usefully be combined with a course of Transkutan baths. X-ray irradiation of the plexus is sometimes of value. Electrical treatment is usually of no benefit. Massage will not be tolerated during the acute stage, but after this has passed light massage combined with gentle exercises promotes recovery.

A careful search should be made for septic foci, especially in the teeth, and these should receive adequate treatment.

INTERCOSTAL NEURITIS

Intercostal neuritis is a rare disorder which is diagnosed much more frequently than it occurs. It is characterized by paroxysmal pain throughout the distribution of an intercostal nerve, associated frequently with cutaneous tenderness in the area supplied by the nerve, especially at the point of emergence of its lateral cutaneous

branch. Before diagnosing intercostal neuritis the utmost care must be taken to exclude the many other disorders which may be associated with pain of this character. Such pain may be due to inflammation of spinal posterior roots, especially in syphilis, or their compression by a neoplasm of the spinal cord. It may follow an attack of herpes zoster. The spinal nerve may be compressed as a result of localized collapse of the vertebral column, most commonly due to tuberculous caries, secondary carcinoma, or traumatic lesions. *Spondylitis is often associated with root pains, and these may also be produced by scoliosis.* Pleurisy, both tuberculous and neoplastic, is sometimes mistakenly diagnosed as intercostal neuralgia, and the thorax is a common site of referred pain in visceral disease, especially in mitral stenosis and diseases of the upper abdominal viscera.

Treatment.

Intercostal neuritis should be treated with analgesics and counter-irritants. X-ray irradiation may relieve an intractable case, and if all else fails the nerve may be injected with alcohol, care being taken that the needle does not penetrate the pleura.

ANTERIOR CRURAL NEURITIS

Symptoms.

Anterior crural neuritis is usually of subacute onset, the pain beginning in the groin and radiating to the front of the thigh and down the inner aspect of the leg to the ankle in the distribution of the internal saphenous nerve. The pain is aching or burning in character, with paroxysmal exacerbations, and is usually associated with feelings of numbness and tingling of the same distribution. The quadriceps becomes weak, and in consequence the knee may give way *when the patient attempts to walk. Weakness of the quadriceps is* most evident when the patient attempts to lift the weight of the body by extending the knee, as in going upstairs or getting into a bus.

The patient lies in bed with the hip flexed to relax the inflamed nerve, which is intensely tender on pressure in the groin. There is marked weakness of the quadriceps in extending the knee, and the muscle is usually somewhat wasted. There may also be weakness of flexion of the hip, though this is in any case difficult to test on account of the pain. The knee-jerk is diminished or lost on the affected side. Sensory impairment is more common in anterior crural neuritis than in sciatic neuritis, and it is usual to find some blunting of light touch and pin-prick over the cutaneous distribution of the nerve on the anterior and inner aspects of the thigh in its lower two-thirds and along the inner aspect of the leg.

Diagnosis.

Anterior crural neuritis must be distinguished from other lesions of the nerve, which may be compressed by tumours within the pelvis or may be involved in psoas abscess. In these cases the onset is usually more gradual than in neuritis. In every case the pelvis must be thoroughly investigated to exclude neoplasm, and the pelvis and spine X-rayed for evidence of tuberculosis and neoplasm. The femur should also be carefully palpated and X-rayed, for I have known sarcoma of this bone mistaken for anterior crural neuritis.

Anterior crural neuritis is sometimes confused with sciatica, but this cannot occur if attention is paid to the distribution of the pain and other symptoms. In anterior crural neuritis the knee-jerk is reduced or lost but the ankle-jerk is unaffected; in sciatica the reverse is the case. Both anterior crural neuritis and sciatica occasionally occur simultaneously in the same individual as part of a lumbo-sacral plexitis.

Arthritis of the hip is distinguished from anterior crural neuritis by the pain evoked on moving the joint, by the fact that wasting when present involves all the muscles around the joint and is not confined to the quadriceps, and that the knee-jerk is not diminished but tends to be exaggerated.

Prognosis.

Recovery is the rule, the acute stage usually passing off in a few weeks. Weakness of the quadriceps may persist for many months and the knee-jerk may remain diminished for years. Recurrence is uncommon.

Treatment.

The patient must rest in bed and the knee should be supported on a pillow, so that the hip is somewhat flexed and the nerve relaxed. Analgesic drugs will be required, and morphine may be needed in severe cases. Iodide and salicylate may be of value. Counter-irritants may be applied to the groin, and benefit is often obtained from a course of Transkutan baths. If the symptoms have not subsided in two or three weeks, X-ray irradiation of the lumbar nerve-roots, and of the nerve-trunk in the groin, may be carried out. Electrical treatment is of little value, but when the acute stage is passed massage of the quadriceps and gentle exercises will promote recovery. Septic foci should be sought and treated.

SCIATIC NEURITIS (SCIATICA)

The sciatic nerve is probably the commonest site of neuritis. Why this should be so is unknown, though many hypotheses have been

put forward to explain it. In the course of the evolution of the erect posture many changes have occurred in the lumbo-sacral spine and have left traces in the frequent occurrence of congenital abnormalities in this region. The liability to sciatica is probably one of the penalties which man pays for his upright attitude and is an indication that he has not yet completely adapted himself to it. Abnormalities of the lumbo-sacral spine, such as sacralization of the fifth lumbar and lumbarization of the first sacral vertebra, may cause pain of a sciatic distribution but cannot cause neuritis. It is probable that the primary site of the neuritis varies in different cases, being sometimes in the region of the intervertebral foramen and sometimes in the nerve-trunk, the latter being the region primarily affected when sciatica follows a fall on the buttock or the repeated minor traumas attendant upon driving a car with a hard seat or faulty springs.

Symptoms.

In most cases the onset is subacute and sciatica is frequently preceded by lumbar pain. After two or three days of pain in the lumbar spine the pain radiates down the back of one leg from the buttock to the ankle. The pain is of a severe aching or burning character, subject to paroxysmal exacerbations, and in severe cases interferes with sleep. It is intensified by stooping, sitting, and walking. The patient is usually most comfortable lying in bed on the sound side with the affected leg slightly flexed at the hip and knee. Occasionally, however, when the pain is very severe he can obtain relief only by getting up and walking about. Coughing and sneezing, which raise the pressure both within the spinal theca and within the pelvis, often cause a momentary exacerbation of the pain. The patient often complains of a feeling of numbness, heaviness, or deadness in the leg, especially in the calf and in the sole of the foot. There are muscular hypotonia and slight wasting, not only of the muscles supplied by the sciatic nerve, but usually also of the glutei and sometimes of all the muscles of the lower limb. There is usually slight weakness of the flexors of the knee and of all the muscles below the knee, that is, those muscles which are innervated by the sciatic; but movements of the hip may also be impaired on account of the pain. The ankle-jerk is diminished or lost, since the calf muscles are innervated by the sciatic nerve. The knee-jerk is often exaggerated, partly as a reflex result of the pain and partly owing to hypotonia of the hamstrings, the antagonists of the quadriceps. The plantar reflex is flexor. The sciatic nerve is tender on pressure in the buttock and thigh, and stretching the nerve by extending the knee with the hip flexed causes severe pain—Lasègue's sign. There is rarely any sensory loss, though occasionally there is slight blunting of light touch and

pin-prick over the *foot* and *lower part of the outer aspect of the leg*.
I have known a simultaneous neuritis of the sciatic and small sciatic
nerves, in which case there were anaesthesia and analgesia over the
cutaneous distribution of the latter in the lower half of the posterior
aspect of the thigh. *Scoliosis is often associated with sciatica*, the
lumbar spine being flexed usually towards the affected side, less
frequently towards the opposite side. An excess of protein and of
mononuclear cells is sometimes found in the cerebro-spinal fluid.
Bilateral sciatica is extremely rare.

Diagnosis.

The sciatic nerve is liable to compression at various points in its
course between the spinal cord and the thigh. Within the spinal
canal the nerve-roots may be involved in compression by tumours
of the cord or of the cauda equina or by a prolapsed intervertebral
disk, or may be the site of inflammation due to syphilis. The spinal
nerves may be compressed within the intervertebral foramina as a
result of disease of the vertebral column. Vertebral collapse may be
caused by caries of the spine due to tuberculosis or other forms of
chronic osteitis, primary or secondary neoplasm or trauma. Infection
due to spondylitis may extend to the nerves, and subluxation or
other abnormalities of the fifth lumbar vertebra may compress the
lumbro-sacral cord, which may also suffer, as it lies in front of the
sacro-iliac joint, from tuberculosis of this joint, from compression by
secondary carcinoma of the internal iliac glands, or from involvement
in psoas abscess. Within the pelvis, infection may spread to the nerve
from an inflamed appendix or diverticulum of the colon, and *com-
pression may arise from a neoplasm, from the pregnant uterus*, or
from the foetal head during delivery. As the nerve passes through
the sciatic notch it may be compressed by sarcoma or aneurysm of
the gluteal artery. Within the buttock it is subject to various forms
of trauma and, *as it lies behind the hip-joint, it may be involved in* an
extension of inflammation from arthritis of the hip. The nerve itself
may be the site of tumours, such as neurofibroma, or rarely sarcoma
or angioma.

It is important, therefore, to distinguish the *symptoms of sciatic
neuritis* from those of *sciatic compression*. The principal points of
distinction are that in neuritis the onset of symptoms is fairly rapid,
the nerve is markedly tender on pressure, muscular wasting is slight,
sensory loss is absent or very slight, and the course of the disorder
during the first months after the onset is stationary or tends to im-
provement. In sciatic compression the onset is usually gradual, the
*nerve is not tender on pressure, muscular wasting is conspicuous, and
sensory loss is always present*. Further, both of these symptoms are

progressive. An exception to this is compression by a herniated intervertebral disk (see p. 634). Sciatic pain due to this cause is usually associated with pain and rigidity of the lumbar spine. Motor and sensory symptoms in the lower limb are often non-progressive and may be slight. Radiography after the lumbar injection of lipiodol is needed to confirm the diagnosis.

Before a diagnosis of sciatic neuritis is accepted, the abdomen and pelvis must be thoroughly examined for possible sources of compression, and the lumbar spine and pelvis should be X-rayed to exclude bony abnormalities, especially spondylitis and congenital malformations of the lumbo-sacral region. Attention must also be paid to the general condition of the patient, and inquiry made for symptoms suggestive of a pelvic neoplasm and as to recent loss of weight. Rectal examination should never be omitted, and in women vaginal examination is advisable also. A complete examination of the nervous system is required to exclude tumours of the spinal cord and syphilis as a cause of sciatic pain, and if these are suspected the cerebro-spinal fluid should also be examined.

The distinction of sciatica from anterior crural neuritis has been described in the section dealing with the latter.

Sciatica requires to be distinguished from arthritis of the hip-joint, with which, however, it may be associated. In sciatica movements of the hip-joint are painless, provided the sciatic nerve is not stretched. The lower limb can be rotated and abducted without pain, whereas these movements are painful and often limited in arthritis of the hip. In the latter condition the ankle-jerk is preserved.

Lumbar and sacro-iliac strain may be confused with sciatica. In these conditions, however, pain and tenderness are situated in the lumbar spine and over the sacro-iliac joint respectively, and though the pain may be intensified by movements of the spine or by lifting the legs from the bed, it does not usually radiate below the knee and the ankle-jerks are preserved.

Vascular lesions within the distribution of the femoral artery, such as atheroma and thrombo-angeitis obliterans, are occasional causes of pain in the leg in middle age and later in life. Intermittent claudication is not always present in these cases. The diagnosis is readily established by diminution in the volume of the femoral, dorsalis pedis, or posterior tibial pulses.

Prognosis.

In mild cases the stage of severe pain lasts only two or three weeks and the patient recovers in a month or two, except that he may from time to time experience aching in the course of the nerve and stooping may still excite some pain in the affected leg. In more

severe cases there may be slight improvement after several weeks, but the condition then becomes stationary and the patient continues to suffer from considerable pain for a number of months. Recovery, however, ultimately occurs, except for the residual disabilities just mentioned. Relapses are common. In some cases they occur at frequent intervals, so that the patient is hardly free from pain over a period of several years. In other cases the second attack may be delayed until ten or more years after the first.

Treatment.

The patient must be kept at rest in bed. Analgesic drugs will be required, including morphine in the most severe cases. A course of iodide and salicylate should be given. Counter-irritation may be applied along the course of the nerve, and radiant heat, galvanism, and diathermy may exert a sedative action. X-ray irradiation of the nerve-roots and trunk in many cases gives a marked relief after the acute stage is passed. A combination of heat and counter-irritation applied in the form of Transkutan baths is often more effective than any other form of treatment. If the patient can stand immobilization, the limb may be fixed by means of a long Liston splint for a period of three weeks.

Epidural Injection.

In obstinate cases injection of the nerve-roots or trunk may be considered. Benefit may be derived from stretching the former by epidural injection at the sacro-coccygeal foramen. This can readily be palpated at the lower end of the sacrum, where it is covered by the posterior sacro-coccygeal ligament. The foramen is bounded above by the concave lower border of the sacrum in the middle line and at the sides by the two lateral tubercles. The patient either lies on one side or assumes the knee-elbow position. The site of the injection is painted with iodine and anaesthetized with novocain, and a fine lumbar-puncture needle is passed through the ligament upwards and slightly forwards. Twenty c.c. of 1 per cent. novocain solution are first injected, and this is followed by an injection of normal saline, of which 80 c.c. or more can usually be injected, the solutions being at body temperature. The object of the injection being to stretch the nerve-roots, a sufficient volume of saline must be injected to raise the tension in the epidural space. It is necessary, therefore, to continue injecting saline until a considerable resistance is encountered, provided always that it does not cause severe pain. Epidural injection yields relief of pain in about 50 per cent. of cases. Sometimes the result is dramatic, the patient being completely and permanently relieved. A second injection may be given after an in-

terval of two or three days if necessary. Various other solutions have been used for this injection, but they do not appear to possess any advantage over saline, which has the additional recommendation of being perfectly safe.

Injection of the Nerve trunk

Injection of the nerve-trunk is sometimes of value in obstinate cases, though it is less easy to carry out successfully than epidural injection. The nerve is injected in the buttock, its position being ascertained as follows: the sciatic notch is marked on the skin at a point 4 in. lateral to the top of the intergluteal cleft and 4 in. above the tuber ischii. From this point the nerve passes outwards and downwards, to lie midway between the tuber ischii and the great trochanter. The course of the nerve is marked on the skin and the injection made $1\frac{1}{2}$ in below the sciatic notch The skin having been painted with iodine and anaesthetized with novocain, a needle 4 or 5 in. in length is introduced at right angles to the skin as far as the sciatic notch. When the nerve is penetrated, the patient experiences a shock-like sensation which radiates down the course of the nerve. When this occurs, 1 c.c. of normal saline is injected, and if the point of the needle lies within the nerve-trunk this injection causes pain in the foot. Two c.c. of 2 per cent. novocain solution is then injected into the nerve as an anaesthetic, and this is followed by 50 to 80 c.c of sterile normal saline solution at body temperature. If the first injection of saline causes no pain in the foot, the point of the needle is not in the nerve and this must again be sought. Throughout the procedure care must be taken that the needle remains in its original position, as a slight movement may cause it to escape from the nerve A successful injection distends the nerve-sheath, and this method of treatment produces benefit probably by breaking down adhesions within the sheath. The injection can be repeated if necessary a few days later.

The injection of oxygen into the deep tissues of the back of the thigh has been advocated for the treatment of sciatica, but this is not without risk and at least one fatality has occurred. The intrathecal injection of alcohol seems hardly justifiable for a simple neuritis. In very resistant cases it may be worth while to try stretching the nerve under an anaesthetic by forcible flexion of the hip with the knee extended. The older method of stretching the nerve after exposing it surgically in the thigh has fallen into disuse.

As soon as the stage of severe pain is past the lower limb should be massaged daily, and the masseur should gently stretch the nerve by flexing the hip with the knee extended. During convalescence the patient should practice stooping with the knees extended. Focal

sepsis should always be sought and treated, and the patient must be instructed to avoid exposing the nerve to trauma, for example, by driving a car, if this appears to have precipitated the attack.

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DISORDERS OF MUSCLE

1. THE PHYSIOLOGY OF MUSCLE

A VOLUNTARY *muscle is composed of muscle fibres each of which is* a multinucleated cell, consisting of contractile substance with a sarcolemmal sheath and its nuclei and a motor end plate in which the nerve fibre terminates   There are still gaps in our knowledge of how the *liberation of energy occurs in muscular contraction*   *Muscles contain* a compound of creatine with phosphoric acid termed phosphagen The liberation of energy involves a cycle in the course of which phosphagen is broken down and resynthesized and glycogen is broken *down into lactic acid.   As a result, creatinine, which is the anhydride* of creatine, is excreted in the urine   Creatine is not normally excreted by the adult male, but it is excreted by children and by some adult females. Creatine appears in the urine also in wasting diseases, such *as diabetes and exophthalmic goitre, in muscular dystrophy and* sometimes in myasthenia gravis

An important advance in the physiology of muscular contraction was the discovery of a humoral element in the transmission of the *nervous impulse at the myoneural junction* *Dale's (1934) observation* that acetyl-choline played a part in this process has afforded an explanation for the action of prostigmin in temporarily abolishing the fatiguability in myasthenia gravis, since this drug is believed to prolong the action of acetyl-choline at the myoneural junction by inhibiting an esterase which otherwise destroys it   The action of quinine in diminishing myotonia may be due to an opposite effect, but recent work suggests that *its action is directly upon the muscle.*

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2. MYOFIBROSITIS

Synonyms: Myositis ; fibrositis ; muscular rheumatism.

Definition: An acute, subacute, or chronic inflammation of the connective tissue of a muscle, giving rise to pain and tenderness.

Aetiology.

The precise cause of this common disorder is unknown. Cold is often a predisposing factor, either in the form of a general chill or a local draught, and myofibrositis of the upper spinal muscles is common in those who drive in an open car. The condition may also follow trauma involving muscular strain. It is generally regarded as due to infection with an organism similar to that responsible for chronic arthritis and interstitial neuritis, and this in some cases at least has its primary focus in the teeth or tonsils, but the undoubted familial tendency to muscular rheumatism suggests that a metabolic factor may play a part.

Pathology.

An inflammatory serous exudate is present in the connective tissue of the affected muscles during the acute stage, and later the symptoms may be maintained by the formation of nodules of fibrous scar-tissue.

Symptoms.

The onset is often acute, the pain being frequently first noticed after a sudden movement. There is an aching or burning pain in the muscle, which is intensified by movements involving its contraction and is attended by tenderness on pressure. When the lumbar muscles are involved the pain may be very severe and movement much hampered. As a rule there is no constitutional disturbance.

Almost any of the muscles may be affected. Stiff neck, one form of torticollis, is due to myofibrositis, either of the sternomastoid or of the posterior cervical muscles, the head being held tilted to one side. 'Cephalodynia' is the term applied to myofibrositis of the muscles attached to the skull. In 'pleurodynia' the muscles of the thoracic wall and those superficial to it are affected. 'Lumbago' is the term applied to myofibrositis of the lumbar muscles.

Diagnosis.

Myofibrositis must be distinguished from painful conditions due to lesions of the nervous system, especially of the posterior roots, in which pain is as a rule associated with hyperalgesia or analgesia of a spinal segmental distribution. Torticollis due to myofibrositis must be distinguished from caries of the cervical spine and from spasm of the sternomastoid secondary to cervical adenitis. A diagnosis of lumbar fibrositis should only be accepted when other causes of lumbar pain have been excluded. Tuberculous caries, secondary carcinoma, and spondylitis of the lumbar spine, traumatic collapse

of the vertebrae (Kümmel's disease), and sacralization of the fifth lumbar vertebra can often be diagnosed with certainty only radiographically. In patients suffering from lumbar strain the lumbar spine is usually tender rather than the muscles, and the pain is most evident on stooping and rising from the stooping posture. In strain and infection of the sacro-iliac joint the tenderness is situated over the joint, and the pain is increased by compressing the iliac crests and by flexing the hip with the knee extended. Pain may be referred to the lumbo-sacral region from diseased pelvic viscera, and may also be hysterical in nature.

Prognosis.

After a few days the acute stage terminates either in recovery or in a chronic stage in which the pain is less severe. Relapses are common.

Treatment.

In the acute stage the patient should be kept at rest in a warm room and heat should be applied to the affected part. This is most simply done by means of a hot-water bottle, but radiant heat and diathermy may be employed. Counter-irritants are useful and may take the form of a mustard leaf, or counter-irritation may be combined with massage in the form of various liniments, or with heat by means of Transkutan baths. Iodide and salicylate should be given in a mixture, and adequate doses of aspirin or other analgesics. In severe cases of lumbago morphine may be required. When the acute stage is past vigorous massage and passive and active movements of the affected muscles should be carried out. Persistent painful nodules should be treated by the injection of a few drops of alcohol into the tender spot after preliminary anaesthetization with novocain. Careful search should be made for septic foci in the teeth, tonsils, nasal sinuses, and elsewhere, and these, if found, should receive appropriate treatment.

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3. DERMATOMYOSITIS

Definition: A rare disorder characterized by inflammation of the muscles and of the overlying skin.

Pathology.

Any or all of the muscles may be involved. Histologically, affected muscles are oedematous and exhibit varying degrees of degeneration

of their fibres. An inflammatory infiltration is present in the peri-
vascular connective tissue and in the connective tissue between the
muscle-bundles. In the later stages fibrosis is conspicuous. The
skin exhibits a firm oedema, with infiltration with yellowish serous
fluid.

Aetiology.

The histological changes and the occurrence of fever and splenic
enlargement indicate that the disorder is probably inflammatory,
but the causal organism is unknown. The disease usually occurs
during adult life.

Symptoms.

The onset is usually subacute and is characterized by malaise
and pain in the extremities. After two or three weeks the muscles
first attacked become tender and rigid. The skin overlying them is
swollen but pits little, and is usually the site of an erythematous or
urticarial eruption. The muscles are attacked successively, and all
the muscles of the body may be involved. There is moderate fever,
with considerable sweating, and the spleen is often enlarged. Stoma-
titis may be present. The muscular rigidity causes great limitation of
movement and muscular contractures may occur. Steiner describes
an acute form, with a duration of from two weeks to two months, a
subacute form, lasting two to eight months, and a chronic form, lasting
one and a half to two years.

Diagnosis.

The diagnosis from trichinosis and suppurative myositis is best
made by excision of a portion of muscle and histological examination.

Prognosis.

The outlook is serious, for seventeen out of twenty-eight of Steiner's
patients died. Death usually occurs from broncho-pneumonia, the
result of the rigidity of the respiratory muscles. Klingman has de-
scribed a form of dermatoneuromyositis terminating in sclerodermia,
but his cases did not all present the typical picture of dermato-
myositis.

Treatment.

Heat should be applied to the muscles, and diathermy may be
employed for this purpose. Massage and exercises may be of value
if the patient can tolerate them. Aspirin should be given for the
relief of pain, and in severe cases morphine will be required.

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4 EPIDEMIC MYALGIA

Epidemic myalgia, or Bornholm disease, is due to an unknown
infective agent. A large epidemic occurred in 1931 in Southern Sweden
and Denmark, but it has been observed in many other countries in-
cluding England and North America It is a febrile illness and its
victims are usually between the ages of ten and twenty-five years.
The onset is usually sudden and the most characteristic symptom is
pain in the lower chest, precordium, and abdomen The commonest
complications are orchitis and dry pleurisy. Respiration may be
rapid and painful and the muscles of the abdominal wall are usually
tender. The disorder may be mistaken for an 'acute abdomen'. It
runs a benign course, complete recovery occurring in from four to six
days without sequelae Treatment is symptomatic

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5. MUSCULAR DYSTROPHY

Synonyms: Myopathy; myopathic atrophy.

Definition: The muscular dystrophies are a group of disorders of
which the essential feature is a progressive degeneration of certain
groups of muscles. The disease is frequently familial or hereditary,
and a number of forms have been recognized owing to variations
in the distribution of the muscles affected. A given form usually
breeds true, but intermediate forms occur. The distribution of
the muscular wasting is peculiar, and the muscles are affected
independently of any disease of the nervous system. Affected
muscles, either in the same individual or in different forms of
the disease, may show *true hypertrophy*, *pseudo-hypertrophy*, or
atrophy.

Pathology.

Nothing is known about the histological appearance of the muscles in the stage of true hypertrophy. In pseudo-hypertrophy and atrophy the earliest change, according to Buzzard and Greenfield, is swelling of some of the muscle-fibres and increase in the sarco-lemmar nuclei. The striation of these swollen fibres is less marked than usual. After the early stages a number of very small muscle-fibres are found, which, it has been suggested, are formed by a splitting of the hypertrophied fibres. Muscle-fibres can be observed undergoing degeneration and conversion into fibrous tissue. The connective tissue septa between the fibres are increased, and there is a marked interfibrous deposition of fat, to which the increased bulk of the pseudo-hypertrophied muscles is due. Infiltration with round cells and even with multi-nucleated cells is sometimes present.

Aetiology.

A congenital, and in many cases hereditary, abnormality is the primary cause of muscular dystrophy. The mode of inheritance of the disorder is not completely understood, but it appears that different forms may be inherited in different ways. The pseudo-hypertrophic form seems to be usually inherited as a sex-linked recessive and resembles haemophilia in being transmitted by apparently healthy females and manifesting itself usually in males The variety of dystrophy reported by Barnes is probably inherited as a pure dominant More complicated modes of inheritance have been invoked to explain peculiarities in the mode of transmission in certain families, and it has been suggested that in certain cases muscular dystrophy may depend upon the coexistence in the hereditary material of a single individual of two separate genes, both of which may be either dominant or recessive.

We do not know what is the nature of the hereditary fault, nor whether it lies in the structure of the muscles themselves, in a disorder of their metabolism, or in their control by endocrine or other factors. The peculiarities of the distribution of the atrophy have been explained in terms of foetal development, and it has been suggested that the muscles which first become differentiated in the embryo are those most likely to be affected in dystrophy. It is difficult, however, to reconcile this explanation with the influence of inheritance. Although cases have been reported in which trauma and infections have been followed by the development of dystrophy, it is probable that these have operated merely as precipitating factors in an individual who was already constitutionally predisposed to dystrophy.

Symptoms.

The following are the more important clinical varieties of muscular dystrophy.

Dystrophia Musculorum Hyperplastica (Hypertrophia Musculorum Vera).

This is a very rare form of dystrophy, which, however, assumes importance when considered in relation to the other varieties. It usually affects adult males and is characterized by excessive muscular development which may be generalized or may be limited to one or two limbs. Although in most cases the hypertrophied muscles are weaker than normal, yet in the early stages the sufferer may be endowed with exceptional strength. This occurred in Spiller's (1913) case and in the first stages of the dystrophy described by Barnes (1932). It appears, therefore, that true muscular hypertrophy with increased power may precede pseudo-hypertrophy, and the relationship between hyperplastic muscular dystrophy and the other varieties is confirmed by the occasional association in the same individual of muscular hypertrophy, with increased power in some muscles, and atrophy and weakness in others. Cramp-like pains have been described as occurring in the hypertrophied muscles There is no record of the histological appearance of the muscles in the stage of hypertrophy. By the time that weakness has set in they present the same appearances as the muscles in pseudo-hypertrophy.

Pseudo-hypertrophic Muscular Dystrophy.

This is the commonest variety of muscular dystrophy and was the first to be recognized, by Duchenne (1886). It usually appears in childhood about the middle of the first decade of life. It is rare for the onset to occur after puberty, but occasionally symptoms are observed for the first time in middle life. Although the disorder may occur sporadically, it frequently affects several siblings. A history of the disorder in previous generations is inconstant Males are affected at least six times as frequently as females, and it appears usually to be inherited as a sex-linked recessive.

The onset is gradual. A child which has previously been normal begins to walk clumsily, tends to fall, and after falling has difficulty in getting up unaided. Examination at this stage reveals enlargement, pseudo-hypertrophy, of some muscles and wasting of others. The distribution of these muscular changes is remarkably constant. The muscles which most frequently exhibit pseudo-hypertrophy are the calves, the glutei, the quadriceps, the infraspinati, and the deltoids (Fig. 72). The supraspinati and triceps may also be enlarged

less frequently the biceps, and occasionally the serratus magnus, the muscles of the forearms, and the masseters. The pseudo-hypertrophied muscles are firmer than normal to the touch, and in spite of their appearance are weak. Wasting is almost always present in the sternal part of the pectoralis major and in the latissimus dorsi,

Fig. 72. A case of pseudo-hypertrophic muscular dystrophy.

It may also be present in the serratus magnus and the muscles of the limbs, the proximal muscles being more liable to waste than the distal ones. The muscles of the face and hands always escape. Ultimately wasting develops in most cases in the muscles which previously exhibited pseudo-hypertrophy.

The peculiar distribution of the muscular weakness leads to characteristic disorders of the stance and gait. Weakness of the glutei, the extensors of the trunk and hips, causes the patient to assume an attitude of lordosis when standing, the trunk being thrown back, as in pregnancy, to displace the centre of gravity behind the

vertebral column and thus throw the task of maintaining it upright upon the flexors rather than upon the extensors of the hips. The patient adopts a waddling gait, somewhat similar to that seen in congenital dislocation of the hips. Weakness of the extensors of the spine and knees leads to the adoption of a characteristic method of rising from the ground, the patient turning over on to the hands and feet and assisting himself into the upright attitude by clasping his legs with his hands and 'climbing up' his own legs.

Muscular fibrillation is absent, but the muscles exhibit the electrical reactions associated with muscular atrophy. The tendon reflexes are diminished and ultimately lost, both in the pseudo-hypertrophied and in the atrophied muscles. Sensation is unimpaired and intelligence is usually normal.

The Muscular Dystrophy of Barnes.

Barnes (1932) has described a family in which a unique variety of muscular dystrophy has appeared in five successive generations and which presents points of interest in relation to other varieties. The sexes are affected about equally, and it appears to be inherited as a Mendelian dominant. The age of onset varies between 9 and 50. The first stage is a true muscular hypertrophy associated with abnormal strength. This gives place usually in middle life to progressive weakness, the muscles remaining enlarged, the stage of pseudo-hypertrophy. Weakness is first apparent in the flexors of the hips. Atrophy then develops in the enlarged muscles, beginning in the thighs and legs, and finally muscular atrophy not preceded by pseudo-hypertrophy makes its appearance in the small muscles of the hands. The disease is not incompatible with the normal span of life.

Other Varieties of Muscular Dystrophy.

The remaining varieties of muscular dystrophy are less sharply differentiated from each other than from the pseudo-hypertrophic form, from which they differ in that pseudo-hypertrophy does not occur, the sexes are more equally affected, hereditary influence is more evident, the age of onset is usually later, and the progress of the disorder is slower. Nevertheless, intermediate forms between the pseudo-hypertrophic and the other varieties of dystrophy are encountered, while the other forms themselves cannot always be sharply differentiated from each other.

In the *Leyden-Möbius* type pseudo-hypertrophy is absent and the wasting predominates in the lower limbs.

In the *facio-scapulo-humeral dystrophy* of Landouzy and Dejerine (1885, 1886) the onset usually occurs during childhood. Weakness and

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wasting first appear in the facial muscles. Weakness of the orbicularis oculi renders pouting and whistling impossible. The zygomatici suffer early, causing weakness of retraction of the angle of the mouth, which is conspicuous in smiling. There may also be weakness of closure of the eyes and of wrinkling the brow. The resulting 'myopathic facies' is distinctive. Atrophy next involves the muscles of the shoulder-girdle and arm, and later the trunk and lower limbs.

In the *juvenile dystrophy* of Erb (1883), so called because the onset usually occurs between the ages of 15 and 35, wasting usually begins in the arm- and shoulder-muscles, later involving the trunk and lower limbs. The face usually escapes, but may be affected.

Gowers (1902) and others have described a *distal form*, in which wasting begins in the hands and forearms and in the legs below the knees. In some cases the legs alone may be affected for many years. A *late type*, beginning in middle age, has been described by Nevin (1936).

Involvement of the ocular muscles in dystrophy is extremely rare. Gowers has described one case, and I have seen an apparent example of this in a woman aged 20 in whom there was complete bilateral external ophthalmoplegia with normal pupillary reactions, associated with enlarged and somewhat weak calf-muscles and sluggish ankle-jerks.

In these varieties of dystrophy muscular atrophy is associated with the usual electrical changes and with diminution and ultimately loss of the tendon reflexes. Muscular fibrillation, though very exceptional, has been described. Sensory changes are absent.

A diminution in the urinary excretion of creatinine and the occurrence of creatinuria in muscular dystrophy are probably secondary to the loss of muscle tissue.

Prognosis.

The pseudo-hypertrophic form is almost invariably progressive, the only exceptions being some cases in which the dystrophy is discovered after the age of 20. Muscular weakness increases until the patient is unable to walk. Contractures develop, especially in the hamstrings and calf-muscles, and there is often severe scoliosis. The disease usually terminates fatally in from ten to fifteen years after the onset, paralysis of the respiratory muscles leading to death from pneumonia.

The progress of the other varieties is always slower than in the pseudo-hypertrophic form, and contractures are less liable to occur. Sometimes the disease appears to become arrested, and in a few cases even improvement has been described. When the onset occurs in childhood the condition is likely to terminate fatally from respiratory

complications, though even so, life may be prolonged for twenty years or more. When the onset occurs after 20 the disease does not necessarily shorten life.

Diagnosis.

Diagnosis of the muscular dystrophies rests upon the onset, usually at an early age, of symmetrical muscular wasting, with a distribution which cannot be explained in terms of the innervation of the muscles In the pseudo-hypertrophic form the presence and distinctive distribution of the enlarged, firm, but weak muscles is pathognomonic. The occurrence of other cases in the family, though not invariable, affords confirmatory evidence.

Poliomyelitis is distinguished by the acute onset and the asymmetrical and non-progressive character of the muscular wasting Progressive muscular atrophy usually develops later in life than the dystrophies. Unlike the dystrophies, it frequently begins in the small muscles of the hands, and muscular fibrillation is always conspicuous. Dystrophia myotonica is distinguished by the presence of myotonia and by the peculiar distribution of the muscular wasting, especially by the characteristic involvement of the sternomastoids, which are rarely affected in the other dystrophies. In peroneal muscular atrophy the muscular wasting begins in the feet and hands and gradually ascends the limbs, involving the peripheral before the proximal parts of the muscles. Sensory changes are present, especially in the lower limbs. Progressive hypertrophic polyneuritis is distinguished from the dystrophies by the occurrence of sensory changes and by the fact that thickening of the peripheral nerves can usually be discovered on palpation. Amyotonia congenita and progressive muscular atrophy of infancy are easily recognized on account of the congenital origin of the former and the onset of the latter during the first year of life.

Treatment.

No treatment can be relied upon to have any influence in retarding the progress of the dystrophies. Glycine has been given in doses of 10 to 20 gm. daily but is of doubtful value in most cases, though a few seem to improve while taking it and many deteriorate more rapidly when it is stopped. Massage may help to maintain the nutrition of the muscles and may delay the development of contractures. As long as possible the patient should be encouraged to walk. If contractures develop, tenotomy is advisable if they do not respond to treatment with extension apparatus. In the later stages the patient should be protected from the risk of respiratory infections.

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6. DYSTROPHIA MYOTONICA

Synonym: Myotonia atrophica.

Definition: A hereditary disorder characterized by muscular dystrophy, myotonia, and other dystrophic disturbances, especially cataract and gonadal atrophy, and by the occurrence of cataract in members of preceding generations of the same family. It was first described by DeKage (1890).

Pathology.

The most prominent feature of the disease is the muscular atrophy which affects particularly the sternomastoids, the facial and shoulder-girdle muscles, the muscles of the forearms and hands, and the quadriceps The affected muscles, when examined microscopically, do not exhibit a diffuse and uniform atrophy of all fibres, some fibres remaining healthy. Alongside these are fibres showing the early signs of degeneration. These fibres are often abnormally large. Their transverse striations are less than normally distinct, and there is a proliferation of the nuclei of the sarcolemma. When degeneration is complete, muscle-fibres are replaced by connective tissue and fat, and there is a sclerosis of the blood-vessels. There is no evidence that the muscular atrophy is secondary to a lesion of the nervous system Atrophy of the testes and ovaries is characteristic, and Adie and Greenfield (1923) have described abnormalities in the pituitary and in the suprarenals.

Aetiology.

Dystrophia myotonica is one of the most mysterious of hereditary disorders, since as a rule cataract is the only abnormality present in the family for several generations, until there is a sudden out-break, in one generation, of the dystrophic disturbances, subsequent generations being usually free from all symptoms of the disorder. The disease appears to be essentially degenerative, and there is evidence that its development is often associated with a decline of the *social status of the affected family through several generations. It* exhibits the phenomenon known as 'anticipation', since there is a tendency for symptoms to develop earlier in each successive generation. It is transmitted by both sexes, by both normal and affected individuals but males appear to be affected with the muscular dystrophy more frequently than females

Though in respect of the muscular wasting dystrophia myotonica resembles other forms of myopathy, the myotonia, or involuntary persistence of muscular contraction after its voluntary initiation or after mechanical or electrical stimulation is peculiar to this disorder and to myotonia congenita and myotonia acquisita. It is suggested that the site of this disturbance of function is at the myoneural junction, since it is intensified by acetyl-choline, and by prostigmin and potassium (Russell and Stedman, 1936), and is diminished by quinine (Kennedy and Wolf, 1937). Brown and Harvey's (1939) work, however, indicates a primary muscular disorder.

Symptoms.

Symptoms of the fully developed form of the disorder first appear between the ages of 15 and 40, in most cases between 20 and 30, but

may be found in childhood. In some cases pains in the limbs occur in the early stages. Usually muscular weakness or myotonia is the first symptom noticed by the patient.

Muscular Wasting.

Muscular wasting is usually most conspicuous in the facial muscles, the sternomastoids, which may be completely atrophied, the muscles

Fig. 73. A case of dystrophia myotonica. (Note the myopathic facies and the wasting of the sternomastoids.)

of the shoulder-girdle, of the forearms and hands, the quadriceps, and the muscles of the legs below the knees. The wasted muscles are weak, and, as the sternomastoids are usually severely affected, the patient may be unable to raise the head from the pillow. The rate of development of the muscular atrophy is variable. It may be rapid, widespread wasting developing within a year. More frequently it is very gradual and progresses slowly over a number of years. Pseudo-hypertrophy is rare (Maas, 1937), and fibrillation is absent. The characteristic facies of myotonia atrophica is principally the result of the muscular wasting (Fig. 73). The face is expressionless and the forehead is smooth; the eyelids often droop and the cheeks

are sunken. As in all the myopathies, the muscles which retract the angles of the mouth are more severely affected than those which elevate and depress the lips. The angles of the mouth are, therefore, little retracted in smiling Usually the muscular wasting begins symmetrically, but one side of the body may be affected before the other, and the disorder may be advanced in the limbs before the face is attacked. In atypical cases the sternomastoids facial muscles, supinators and small muscles of the hands may be normal (Maas, 1937). The tendon reflexes are lost in the wasted muscles.

Myotonia.

The voluntary contraction of muscles exhibiting myotonia may itself be slow. The most characteristic feature, however, is a prolonged after-contraction of the affected muscles which persists after the voluntary effort to contract the muscle has ceased. Myotonia varies in its distribution and in its severity from time to time It is intensified by fatigue, emotion, and cold. It may be diminished, uninfluenced, or intensified by repetition of the movement It is usually most evident in the flexors of the fingers, so that the patient has difficulty in relaxing his grasp. It may involve the facial and masticatory muscles, causing difficulty in eating. *In the legs it may interfere with walking and cause the patient to stumble or fall* Myotonia can often be demonstrated as a persistent localized muscular contraction which follows percussion of an affected muscle This is often well seen in the muscles of the thenar eminence and in the tongue.

Electrical Reactions.

Various abnormal electrical reactions have been described as characteristic of myotonia atrophica. Wasted muscles which exhibit no myotonia may show merely a reaction of degeneration. The presence of myotonia may lead to an after-contraction on both galvanic and faradic stimulation similar to that which follows voluntary contraction.

Other Dystrophic Symptoms.

Cataract, as already described, is frequently associated with dystrophia myotonica. It tends to develop at an increasingly early age in successive generations *preceding that in which muscular dystrophy* occurs. At first it may not appear until old age. In subsequent generations it is presenile. Individuals affected with muscular dystrophy often make no complaint of visual impairment and the cataract is only discovered on examination. Sometimes, however, it is

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severe enough to lead to marked visual failure. It takes the form of a star-shaped opacity starting in the posterior, and later affecting the anterior, cortical lamella. There may also be found punctate opacities in other parts of the lens. The cataract ripens quickly in both eyes.

Atrophy of the testes and ovaries is usually present, leading in the male to loss of sexual desire, impotence, and sterility, and in the female to amenorrhoea. These symptoms often do not develop until between 25 and 30. Other endocrine disturbances which may occur include adenoma of the thyroid and diabetes mellitus. Frontal baldness is usually present and is more conspicuous in males than in females. Various psychical abnormalities have been described, but there is no constant mental change. Low intelligence and mental defect, however, are common in affected families.

Diagnosis.

The fully developed form of the disease presents a unique clinical picture which renders diagnosis easy. Myotonia congenita begins in early life and is not associated with muscular wasting. If myotonia be absent when the patient is examined, the condition must be distinguished from other forms of muscular dystrophy. The distinction is based upon the later onset of dystrophia myotonica, the characteristic distribution of the muscular wasting, especially the involvement of the sternomastoids, and the presence of such associated symptoms as cataract and impotence. The distribution of wasting, the absence of muscular fibrillation, and the extra-muscular dystrophic symptoms distinguish the condition from progressive muscular atrophy.

Prognosis.

As already mentioned, the rate of development of the muscular wasting is very variable, but usually the condition progresses slowly over a period of years. Though the patient gradually becomes incapacitated he may live for many years, but usually succumbs to an intercurrent illness during late middle life.

Treatment.

No treatment that will arrest the progress of the disease is known. The patient should lead a quiet life and avoid undue fatigue, but as in the case of all chronic maladies of the nervous system he should be encouraged to remain at work as long as possible and every effort should be made to postpone the final confinement to bed.

Myotonia, if troublesome, may be relieved by quinine hydrochloride in a daily dose of from 10 to 30 grains.

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7. MYOTONIA CONGENITA

monym : Thomsen's disease.

efinition : A rare hereditary disorder characterized by *prolonged* e contraction and retarded relaxation of the muscles, which occur at the beginning of, and after, voluntary movement and following rical excitation.

iology.

has frequently been pointed out that myotonia congenita is ciated with large muscles, though the association is a complex as is shown by the pedigree of Rosett's (1922) family, in which, ough in the second and third generations myotonia occurred in viduals of exceptional muscular development, the latter charactie was inherited from the normal male grandparent, while the itonia was derived from the female grandparent, who was of iter build Microscopically, the muscle-fibres are abnormally large exhibit poor transverse striations and an increase in the sarconar nuclei, changes which recall the condition of the muscles in ido-hypertrophic muscular dystrophy. The central nervous em and peripheral nerves are normal.

iology.

he disorder is usually hereditary, though sporadic cases may occur. sexes are affected with equal frequency, and the abnormal factor ives in inheritance as a Mendelian dominant. Thomsen (1876) self suffered from the disease, and its heredity in his family has

been investigated by his great-nephew Nissen (1923), who has reported examples in seven generations. The nature of the myotonia is discussed on p. 789. Its cause is unknown. The term 'hereditary paramyotonia' has been applied to a hereditary disorder characterized by the occurrence of myotonia only when the sufferers are exposed to cold. It is uncertain whether this should be regarded as identical with myotonia congenita.

Symptoms.

Myotonia is frequently first observed in childhood and is probably usually congenital, though it may not be noticed until the patient has reached adult life. Its essential feature is a prolongation of muscular contraction with slow relaxation. This may follow voluntary muscular contraction, for example, the patient after firmly grasping an object is unable to relax his hold. A similar after-contraction may follow involuntary movement, for example, after sneezing, the eyes may remain closed, the orbiculares only very slowly relaxing. More characteristic, however, is the prolonged contraction of the muscles maintaining the existing posture, which is excited by the patient's endeavour to change his attitude by making a movement. This has been described as 'intention rigidity'. For example, the myotonic child is the last member of the class to stand up, and if a myotonic individual stumbles, he is apt to become suddenly rigid and to fall, because he is unable to save himself. The myotonia may be generalized or localized and is frequently most evident in the lower limbs. During myotonia the muscles are prominent and very hard on palpation. An early symptom is the inability of the patient to look upwards quickly, the attempt to do so causing the ocular muscles to fix the eyes rigidly in a position of horizontal gaze. The severity of the disorder varies in different individuals, even in different members of the same family. In slight cases the patient may be unaware that he is myotonic, and the myotonia may be demonstrable only by special tests. Myotonia is always increased by exposure to cold. A myotonic muscle responds to percussion by a sharp local contraction, which relaxes very slowly. Electrical stimulation, whether with the galvanic or with the faradic current, is followed by a prolonged muscular contraction, which develops more slowly than normally and is very slow in relaxing, the myotonic contraction of Erb. There is no muscular wasting, the reflexes are normal, and sensory abnormalities are absent.

Although mental abnormalities have been described as occurring in families afflicted with myotonia congenita, they form no essential part of the clinical picture. An interesting feature of Rosett's family is the fact that although cyclothymia and myotonia were associated

in the same individual in the first generation, they became separated in the second generation.

Diagnosis.

Myotonia congenita is likely to be confused only with other conditions characterized by prolonged muscular contraction. This is a prominent symptom of dystrophia myotonica, but in this disorder it is associated with muscular wasting, especially of the sternomastoids and quadriceps, and with other dystrophic symptoms, especially cataract, which may occur either in affected individuals or in their ancestors. Tonic perseveration is a prolongation of muscular contraction initiated by voluntary movement, but is due to a disturbance of nervous function. It follows a cerebral lesion which usually involves the frontal lobe and of which other symptoms are present. The muscular rigidity associated with Parkinsonism and other extra-pyramidal syndromes is readily distinguished from myotonia by the fact that it is evident on passive movement, while myotonia is not.

Prognosis.

Myotonia congenita does not shorten life. The severity of the myotonia tends to decrease as the patient grows older.

Treatment.

No cure is known. The myotonia may be relieved by quinine hydrochloride in doses of from 10 to 30 grams a day. Vigorous exercise, though originally recommended by Thomsen, appears to do more harm than good in many cases.

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8. MYASTHENIA GRAVIS

Definition: A chronic disease with a tendency to remissions and
relapses, characterized by abnormal muscular fatiguability, which
may for a long time be confined to, or predominant in, an isolated
group of muscles, and is later associated with permanent weakness
of some muscles. The fatiguability is due to a disorder of conduction
at the myoneural junction, which can be temporarily relieved by
physostigmine and similar drugs. It was first recognized by Wilks
(1887) and described by name by Erb (1879).

Pathology.

The most constant pathological changes in myasthenia gravis are
so-called 'lymphorrhages' in the muscles. These are collections of
small round cells resembling lymphocytes, lying as a rule between
the muscle fibres, but sometimes actually within the fibres. The
muscle-fibres usually show slight degenerative changes, and there
may be actual muscular atrophy. 'Lymphorrhages' may be found
in many muscles, including the myocardium. They are not always
confined to muscles which exhibit myasthenia. In the nervous system
developmental abnormalities have occasionally been observed and
also chromatolysis of the ganglion cells of the anterior horns, but
these changes are slight and inconstant. The thymus gland is enlarged
in about 50 per cent. of cases. This enlargement may be due to a
malignant growth but has sometimes been regarded as a hyperplasia
rather than a neoplasm, and the resulting tumour has then been
called a benign thymoma. Abnormalities in other endocrine glands
have occasionally been described. *Lymphorrhages, fibrosis, and
hyperplasia* have been noted in the thyroid, and in one case there
has been an adenoma in the pituitary. *Lymphorrhages have also*
been observed in the liver, suprarenals, kidneys, lungs, and pancreas.

Aetiology.

Myasthenia gravis is usually seen in adult life, most cases occurring
between the ages of 20 and 50, but the age of onset ranges from 10 to
70. Females are affected more frequently than males. It is not as a
rule familial, but multiple cases in one family have been described.
The essential disorder of function is an impairment of conduction at
the myoneural junction of striated muscles. This is temporarily
relieved by physostigmine and its analogue prostigmin, drugs which
are known to act by inhibiting an enzyme, choline-esterase which
breaks down the acetyl-choline necessary for the conduction of the
nervous impulse to the muscle. Choline-esterase is not present in

excess in the blood in myasthenia, and the exact nature of the myo-neural disorder is unknown.

Both ephedrine and potassium which improve conductivity at the myoneural junction may benefit patients with myasthenia.

There are many obscurities also in the more general aetiology. It has been held that acute infectious diseases are a precipitating cause, and there is no doubt that pregnancy may influence the development of myasthenia, the onset of which may follow pregnancy or labour. On the other hand, cases have been reported in which remissions of the disease occurred during successive pregnancies. The significance of the lymphorrhages in the muscles and of the enlargement of the thymus remains obscure. If the disease is due to some endocrine or general metabolic disturbance it is difficult to understand why the manifestations of these should be confined, as they may be, to one group of muscles for many years. The association of myasthenia gravis with exophthalmic goitre has been observed. Enlargement of the thymus is a common feature of many cases of both disorders. Diminished sugar tolerance, with or without glycosuria, has also been observed not infrequently in myasthenia gravis, together with disturbance of metabolism of creatinine and creatine, but these may well be the results rather than the causes of the disease of the muscles.

Symptoms.

The cardinal symptom of myasthenia gravis is abnormal muscular fatiguability. This is most frequently observed first in the ocular muscles. Less often it begins in the bulbar muscles and sometimes it is generalized from the beginning. The onset is almost always gradual and the disease shows its characteristic fluctuations from the start. Ptosis of one or both upper lids is often the first symptom and is soon associated with diplopia due to paralysis of one or more of the external ocular muscles. These symptoms characteristically appear in the evening when the patient is tired and disappear after a night's rest. When the bulbar muscles are involved, difficulty in swallowing is complained of, again most evident in the evening and often only developing in the course of a meal which the patient begins to swallow without any trouble. Speech may become indistinct when the patient is tired.

On examination unilateral or bilateral ptosis is often found. Weakness of the external ocular muscles is asymmetrical and may progress to complete external ophthalmoplegia of one or both eyes. Occasionally conjugate ocular movements appear to be affected, but more often there is no functional relationship between the muscles involved in the two eyes. Paresis of accommodation has been

described. The pupillary reflexes are usually normal, but may be sluggish or *exhibit fatiguability.*

The facial muscles are almost always affected. Weakness of the orbicularis oculi is perhaps the most constant sign of the disease. In the lower face the retractors of the angles of the mouth tend to suffer more than the elevators and depressors of the lips, with the production of a characteristic snarling appearance on smiling—the myasthenic smile. Weakness of the jaw muscles leads to difficulty in chewing, and weakness of the muscles of the soft palate, pharynx, tongue, and larynx, to difficulty in swallowing and in articulation. Speech becomes slurred and hoarse, and the characteristic fatiguability may be demonstrated by asking the patient to count up to 50, during which speech becomes progressively less distinct. Paresis of the palate often gives a nasal character to the speech and may cause regurgitation of fluids through the nose on swallowing. Weakness of the neck muscles tends to cause the head to fall forward. The upper limbs are usually more affected than the lower: in severe cases the hands cannot be lifted to the mouth. Fatiguability of the muscles of the larynx and of the intercostals and diaphragm often leads to attacks of dyspnoea, which at first occur only after exertion and later even when the patient is at rest. Such an attack may prove fatal.

Permanent paralysis *sooner or later* develops in muscles which at first exhibit only abnormal fatiguability. This is most often seen in the ocular and bulbar muscles. Muscular wasting, though rare, undoubtedly occurs and is encountered in a small proportion of cases. It may be associated with fibrillation.

The Myasthenic Reaction.

Much stress has been laid upon the change in the electrical reactions of the muscles which may be observed in myasthenia gravis. It is found that during faradization with a tetanizing current the muscle gradually loses its power to respond, though *it is still capable of some* voluntary movement. This exhaustion is not produced by the galvanic current. The myasthenic reaction is by no means constantly present in myasthenia gravis, but when it occurs it may be obtained in muscles which do not exhibit fatiguability. It has also been observed in other conditions, so that neither its presence nor its absence is of great diagnostic value.

Sensory symptoms have occasionally been described in myasthenia, the most important of these being generalized pains and feelings of muscular stiffness. *Psychical disturbances* have also been recorded, but it is doubtful whether these should be considered as symptoms of the disease rather than as psychotic reactions which may occur in susceptible individuals who are subject to a severe nervous disorder.

Reflexes.

The pupillary reflexes have already been described. The palatal reflex and the pharyngeal reflex may be diminished when the palatal and pharyngeal muscles are the site of weakness. The tendon reflexes are usually normal, but may be diminished. They sometimes exhibit fatiguability, being normal at first but diminishing and ultimately disappearing after a long series of taps on the tendon. The plantar reflexes are flexor.

Other Symptoms.

Enlargement of the thymus may be demonstrable by percussion over the upper part of the sternum or may be evident on radiography and slight diffuse enlargement of the thyroid is by no means rare. Disturbances of sugar metabolism are not uncommon. Diminished sugar tolerance, with or without glycosuria, is the commonest abnormality, but increased sugar tolerance may occur. There is usually a diminution in the excretion of creatinine in the urine, often with an abnormal urinary excretion of creatine. This disturbance of the creatine-creatinine ratio is attributed to defective muscular function. The blood and cerebro-spinal fluid are normal. A piece of muscle excised during life may show the characteristic lymphorrhages.

Diagnosis.

The diagnosis of myasthenia gravis does not give rise to much difficulty in typical cases if its cardinal features are borne in mind, namely, muscular fatiguability increasing towards evening, relieved by rest and exhibiting a tendency to spontaneous remissions and relapses. The rapid abolition of weakness in a $\frac{1}{2}$ to 1 hour by an injection of 2·5 mg. of prostigmin given with 1/100 gr. of atropine is of great diagnostic value.

Progressive muscular atrophy, whether involving the limbs or the bulbar muscles, is distinguished by the prominence of muscular wasting and fibrillation in the clinical picture, and by the steadily progressive course. In syringobulbia the characteristic sensory loss is present. Pseudo-bulbar palsy is characterized by spasticity in the weak muscles, and is usually associated with signs of a pyramidal lesion in the limbs. The muscular dystrophies are distinguished by the conspicuous wasting with its distribution characteristic of the different forms. In encephalitis lethargica there is usually a history of sleep disturbance, pupillary abnormalities are common, and Parkinsonian symptoms may be present. A so-called 'myasthenic form' of encephalitis lethargica sometimes occurs and may be difficult to distinguish from true myasthenia gravis. Diphtheritic polyneuritis is distinguished by the history of diphtheria, the rapid onset

of bulbar symptoms, and the frequent coexistence of paralysis of accommodation and diminution or loss of the tendon reflexes, especially in the legs. Disseminated sclerosis may lead to confusion, as it is a common cause of transient diplopia. In such cases, however, other signs, such as pallor of the optic disks, nystagmus, absent abdominal reflexes, or extensor plantar responses, will probably be found and ptosis is very rare. Neurosis is a not uncommon cause of fatiguability, especially when it takes the form which may appropriately be designated neurasthenia. Usually, however, neurotic symptoms are worse in the morning and tend to improve as the day goes on, in marked contrast with myasthenia. Moreover, neurotic fatiguability does not lead to true paralysis of the upper lids or of the ocular, palatal, or pharyngeal muscles. The myasthenic electrical reaction is absent in such cases.

Prognosis.

The course of myasthenia is extremely variable. The onset is usually gradual, and ocular symptoms, such as ptosis and diplopia, may recur at intervals over a period of twenty or more years without further symptoms developing. The outlook is best when the ocular muscles are first affected. Even when the bulbar and limb muscles are involved striking remissions may occur and may last for years, or the patient may remain stationary for similar long periods. Occasionally the disease stops short at the neck, and severe ophthalmoplegia and bulbar paralysis coexist with normal power in the limbs. On the other hand, cases have been reported in which the disease proved fatal in a few weeks. In the final stages the patient becomes bedridden and much emaciated owing to difficulty in chewing and swallowing. Attacks of dyspnoea occur and become increasingly frequent. Death usually results from broncho-pneumonia, or during an attack of dyspnoea, or from sudden cardiac failure, the mode of production of which is unexplained.

Treatment.

Complete rest is of great importance, and during an exacerbation the patient must be kept in bed and carefully nursed in the hope that a remission will occur. During remissions fatigue must as far as possible be avoided.

Prostigmin renders those muscles still capable of responding to it temporarily normal. The full subcutaneous dose is 2·5 mg. given with 1/100 grain of atropine. The maximum effect is produced in about an hour and lasts for about six hours. In severe cases full doses are required three or four times a day and should be given an hour before meals. In milder cases oral administration of a 15 mg. tablet three

times a day is often sufficient. When the effect of prostigmin passes off the patient may feel temporarily more fatigued. Potassium may be given either alone or as an adjuvant to prostigmin in doses of 4 to 6 gm. of the chloride six times a day in water. Ephedrine is also sometimes helpful either alone or with prostigmine. A dose of ½ gr. is given several times a day and increased if necessary Glycine may be tried in 15 gm doses twice a day. Anaesthetics and narcotics should be avoided. Much difficulty may be encountered in feeding the patient. *This should be done by a nurse with a spoon, and care must be taken that the pharyngeal muscles are given time to recover from fatigue after each mouthful* Solid food should only be given if chewing does not cause fatigue Exercises, massage, and all forms of electrical treatment probably do harm When the thymus gland is enlarged benefit may follow its irradiation with X-rays.

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9. FAMILY PERIODIC PARALYSIS

Definition: A hereditary disease of unknown aetiology characterized by periodic attacks of flaccid muscular paralysis, which develop abruptly and last from a few hours to three or four days.

Aetiology.

The first case of family periodic paralysis seems to have been observed by Cavaré (1863), and the disorder was described in detail by Westphal and Oppenheim in 1885, its hereditary character being emphasized by Goldflam in the same year. Although sporadic cases occur, in 81 per cent. of cases the disease is hereditary. Holtzapple has reported 17 cases in four generations of the same sibship. It is transmitted by both sexes, but males are affected twice as frequently as females.

The cause of the disorder is still incompletely understood. Though it has been regarded as nervous in origin, it is now thought to be essentially a disorder of muscular function which occurs independently of any nervous abnormality. In susceptible persons attacks can be precipitated by glucose, by insulin or both together, and sometimes by adrenalin. They are attended by a fall in the potassium of the blood serum and by retention of potassium in the body, and are at once relieved by a large dose of potassium. It has been suggested that there is an abnormal demand for potassium in the muscles and that it seems probable that muscles which are inherently abnormal cease to function as a result of a temporary metabolic disturbance. Sporadic cases are encountered as a rare complication of thyrotoxicosis. That family periodic paralysis may be remotely related to the muscular dystrophies is suggested by the reported occurrence of muscular dystrophy in relatives of patients with the former disorder. Family periodic paralysis shows certain points of resemblance to migraine, as McLachlan has recently emphasized. Both may occur in the same individuals or in the same sibship, as in Holtzapple's family, and many of the precipitating causes of attacks are identical in the case of the two disorders. These include exposure to cold, going without

a meal (Collier), indulgence in alcohol, constipation, menstruation, mental excitement, over-exertion, and fatigue.

Pathology.

Few autopsies have been made and no structural abnormality has been found in the nervous system. Biopsies have revealed slight changes in the muscles, for example, degeneration of striated fibres and slight multiplication of the sarcolemmar nuclei, but these may well be secondary to the disorder of function, rather than its cause.

Symptoms.

The attacks may begin in childhood, even as early as the age of 5 or 6. More often they start at puberty, and not uncommonly the onset is delayed until the age of 20 or 21. They almost always occur in the early morning, either while the patient is asleep or shortly after he awakens. They rarely take place during sleep in the day or when the patient is fully awake. Prodromal symptoms, which are not uncommon, include excessive hunger and thirst on the previous day, sweating, diminished salivation and feelings of stiffness, swelling or pain in the limbs or in the whole body, at the time of onset of the attack. The patient may awaken with these prodromal symptoms or already partly or completely paralysed, and not uncommonly bathed in sweat. The paralysis usually reaches its maximum in about an hour. The muscles of the limbs are chiefly affected and the proximal muscles suffer more than the distal, the fingers and toes rarely being completely paralysed. The paralysis is usually symmetrical and is sometimes confined to the lower limbs, less frequently to the upper, but monoplegia and hemiplegia may occur (McLachlan). The muscles of the abdomen are usually affected, but the internal and external ocular muscles and the bulbar muscles concerned in speech and swallowing usually escape. In severe cases the respiratory muscles become weak and weakness of expiration may render phonation, coughing, and sneezing impossible. The paralysed muscles usually feel somewhat firm and are not hypotonic. The tendon reflexes are lost during the attack, and impairment of the abdominal reflexes has also been described. The electrical excitability of the muscles both to faradic and to galvanic stimulation is usually lost during the attack. Consciousness is preserved and sensibility remains normal. Cardiac dilatation and arrhythmia have been described, and Janota and Weber have noted abnormalities in the electrocardiogram. Urine may not be passed during an attack which lasts from twelve to twenty-four hours, but in longer attacks micturition occurs as the bladder becomes distended. The function of the

sphincters is usually unimpaired. Creatinuria has been observed, increasing during attacks.

The attacks last from a few hours to three or four days. The *muscles first attacked are usually the first to recover,* and recovery, when once it begins, is rapid. Abortive attacks may occur, in which the prodromal symptoms are not followed by paralysis. Some of McLachlan's patients found that they could abort an attack by 'walking it off'. *Patients who have been subject to the disorder for many years may exhibit permanent changes in the muscles,* for example, loss of tendon reflexes and fibrous thickening, with or without paresis. There are great variations in the frequency of the attacks. They may occur every few days, or they may be separated by intervals lasting several years. *A patient of Kaufmann had attacks every four or five days in the winter and every four to six weeks in the summer.* The menstrual periodicity may determine the frequency of the attacks.

Diagnosis.

There should be little difficulty in making a correct diagnosis in the familial cases. A sporadic case may be regarded as hysterical, but the loss of tendon reflexes and the electrical changes in the *muscles are never found in hysteria.* Family periodic paralysis is distinguished from cataplexy by the long duration of the loss of power, and from epilepsy by the retention of consciousness and the absence of convulsions. The temporary nature of the paralysis distinguishes it from Landry's paralysis, poliomyelitis, and the various muscular dystrophies.

Prognosis.

Death occasionally occurs during an attack as a result of respiratory paralysis, but this is exceptional. The attacks usually attain their maximal severity between the ages of 20 and 30, after which they tend to become slighter and ultimately to disappear, though they may continue to occur up to the age of 50 or 60.

Treatment.

Prophylactic treatment should follow the same lines as in migraine, and the patient should be instructed to avoid, as far as possible, *everything which is likely to precipitate an attack, especially* exposure to cold, excessive consumption of sugar, fasting, and overexertion. Phenobarbital and bromide may possess some prophylactic value. At the onset of an attack 12 gm. of potassium chloride should be given by mouth. When attacks occur frequently smaller doses, such as 3 gm. may be given regularly twice to four times a day.

Artificial respiration may be required to tide the patient over respiratory paralysis and is best carried out by means of a Drinker or Bragg-Paul respirator.

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10. MUSCULAR DISORDERS ASSOCIATED WITH THYROID DISEASE

The relationship between the thyroid gland and the muscles is still very little understood. That such a relationship exists, however, is shown by the association of disorders of muscle with hyperthyroidism and, less frequently, with hypothyroidism.

1. Exophthalmic Ophthalmoplegia.

The association of this syndrome with the thyroid is indirect It is a disorder which attacks males more often than females and is usually seen in middle life. It may arise spontaneously in which case it is usually accompanied by symptoms of hyperthyroidism which, however, are not as a rule severe. Some of the most marked examples, however, have been observed after thyroidectomy for hyperthyroidism in patients whose basal metabolic rate has thus been rendered normal or even subnormal. Both exophthalmos and ophthalmoplegia are secondary to changes in the orbital tissues producing extreme oedema. The extra-ocular muscles may be increased in diameter as much as nine times the normal and exhibit lymphocytic infiltration which, if the condition is unrelieved, terminates in fibrosis. These changes cannot be explained as due to thyro-

toxicosis when this is present, but have been ascribed to the thyrotropic hormone of the anterior lobe of the pituitary.

Fig. 74. Exophthalmic ophthalmoplegia.

The syndrome is characterized by progressive exophthalmos associated with ophthalmoplegia in one or both eyes. The muscles most often affected are the external recti and the elevators of the eyes. The adductors and depressors often escape, but in severe cases there is bilateral total external ophthalmoplegia. The muscular

weakness is uninfluenced by prostigmin. The pupillary reactions are always normal. The eyelids may be retracted, but ptosis is commoner. The conjunctiva is oedematous and in severe cases proliferates beyond the outer margins of the eyelids (Fig 74). The cornea may ulcerate. Papilloedema going on to optic atrophy is occasionally seen.

The thyroid may be slightly enlarged, but often is not visibly or palpably so. Tremor and tachycardia are slight or absent. There is usually little loss of weight and the basal metabolic rate is little, if at all, above normal.

Medical treatment is usually unavailing, though benefit has been stated to follow massive doses of thyroid extract. If the sight is threatened either by corneal damage or by optic atrophy the operation of orbital decompression by the transfrontal route should be performed.

2. Acute Thyrotoxic Myopathy.

This is a very rare condition in which in addition to the general symptoms of a severe thyrotoxicosis, exophthalmos, and ophthalmoplegia there is a rapidly developing bulbar palsy, with paralysis of the muscles of mastication, expression, and deglutition and generalized weakness of the limbs. Death always occurs, usually within a week or two of the onset of the bulbar symptoms.

3. Chronic Thyrotoxic Myopathy.

The fatiguability common in thyrotoxicosis is a symptom of disordered muscular function which in more severe cases leads to the insidious development of muscular wasting and weakness. Ophthalmoplegia is usually absent and chronic bulbar palsy is also rare. As a rule the muscular weakness and wasting are limited to the muscles of the trunk and limbs, their distribution is symmetrical, and the muscles of the shoulder-girdle and pelvic girdle are often more conspicuously affected than the peripheral muscles of the limbs. Coarse muscular fibrillation may be seen, and the tendon reflexes are diminished or lost. Creatinuria is usually present.

Little is known about the pathological changes in the muscles, but lymphocytic infiltration similar to the lymphorrhages seen in myasthenia gravis has been described. The prognosis is good, complete recovery usually occurring rapidly after thyroidectomy.

4. Thyrotoxic Periodic Paralysis.

Symptoms indistinguishable from those of periodic paralysis have been reported in association with thyrotoxicosis in a few cases. I have seen one example of this. The prognosis is good, the symptoms disappearing after thyroidectomy.

5. Myasthenia Gravis Associated with Thyrotoxicosis.

The association of these two disorders is not extremely rare. The symptoms of both are typical and the myasthenia is temporarily diminished or abolished by prostigmin. It may be uninfluenced by thyroidectomy.

6. Myotonia Complicating Hypothyroidism.

A small number of cases have been described in which myotonia has been associated with myxoedema. Cramps occurred in the muscles which became very hard and on percussion exhibited localized contraction. This association is unexplained.

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DISORDERS OF THE AUTONOMIC NERVOUS SYSTEM

1. THE AUTONOMIC NERVOUS SYSTEM

THE 'autonomic' or 'vegetative nervous system' is the term applied to that part of the nervous system which is concerned in the innervation of unstriated muscle and many of the secretory glands. Physiologically it is divisible into two parts—the sympathetic and the parasympathetic, which to a large extent are mutually antagonistic in function and which employ anatomically separate pathways.

ANATOMY OF THE AUTONOMIC PERIPHERAL NERVES

In the case of both the sympathetic and the parasympathetic nerves two neurones intervene between the central nervous system and the innervated viscus, the efferent path being interrupted at a ganglion The first neurone, which runs between the nervous system and the ganglion, is termed *preganglionic*. The second neurone, which runs from the ganglion to the viscus, is termed *post-ganglionic*.

Sympathetic Fibres.
Efferent Paths.

The sympathetic outflow from the central nervous system is limited to the region of the spinal cord lying between the first dorsal and the first lumbar segments inclusive.

Preganglionic Fibres. The preganglionic neurones are ganglion cells situated in the lateral horn of the grey matter of the spinal cord between these levels. The axones of these ganglion cells leave the spinal cord by the corresponding anterior roots, from which they pass to the corresponding ganglia of the sympathetic chain. The preganglionic fibres are medullated, and the root by which they pass from the anterior root to the sympathetic ganglion is known as a *white ramus.* Arrived at the sympathetic ganglion, some preganglionic fibres terminate in the ganglion corresponding to the segment at which they leave the cord. Others pass upwards or downwards in the sympathetic chain, to terminate in ganglia above or below. Others again pass through the ganglia of the sympathetic chain emerging by special nerves, to terminate in more peripheral ganglia, the collateral sympathetic ganglia, or sympathetic plexuses, which are usually situated in close relationship with the blood-vessels supplying the principal viscera. The most important of such nerves are the splanchnic nerves. The greater splanchnic nerve is derived

from the ganglia of the sympathetic chain, from the fifth to the ninth or tenth dorsal segments, and runs to the coeliac plexus; the lesser splanchnic nerve, from the tenth and eleventh dorsal ganglia, goes to the aortico-renal plexus, and the least splanchnic nerve, from the eleventh dorsal ganglion, to the renal plexus.

The Sympathetic Chain. The sympathetic chain, which lies close to the vertebral column on either side, consists of a series of sympathetic ganglia possessing for the most part a segmental arrangement, linked together by sympathetic fibres. There are three cervical ganglia—superior, middle, and inferior—eleven dorsal, four lumbar, and four sacral ganglia, all paired, together with one unpaired coccygeal ganglion. Although all the preganglionic fibres emerge from the dorsal and first lumbar segments of the cord, by means of the sympathetic chain they are brought into relationship with spinal nerves throughout the whole length of the vertebral column.

Post-ganglionic Fibres. The post-ganglionic sympathetic fibres are non-medullated. Some arise from ganglion cells in each of the ganglia of the sympathetic chain and pass to the corresponding spinal nerve by a grey ramus, to be distributed to the tissues innervated by this nerve. Other post-ganglionic fibres take origin in collateral ganglia and pass to the various viscera.

Afferent Paths.

Afferent sympathetic fibres, both medullated and non-medullated, enter the nervous system by the posterior roots at all levels, having their ganglion cells in the posterior root ganglia.

Parasympathetic Fibres.

The parasympathetic is also known as the cranio-sacral autonomic nervous system because its outflow is situated in the cranial and sacral regions. Unlike the sympathetic system, the ganglia of the parasympathetic are situated in the immediate neighbourhood of the innervated viscera. Thus the preganglionic fibres are long and the post-ganglionic short. The principal preganglionic fibres of the cranial parasympathetic pass through the third nerve to the ciliary ganglion, through the seventh to the geniculate, spheno-palatine, submaxillary, and otic ganglia, through the ninth to the otic ganglion, and through the vagus to the ganglia of the thoracic and abdominal viscera supplied by this nerve. The vagus is the most important parasympathetic nerve. Its dorsal motor nucleus is the site of origin of the fibres which innervate the viscera it supplies. The sacral autonomic outflow is derived from the second and third sacral segments, and passes to the vesical plexus by the nervi erigentes. The principal afferent fibres of the parasympathetic reach the central

nervous system through the vagus nerve, having their ganglion cells in the ganglion nodosum of that nerve.

Physiology.

The physiology of the autonomic nervous system in respect of various organs is considered below. Certain generalizations which have been made concerning the functions of the sympathetic and the parasympathetic and their mutual antagonism must be mentioned

The sympathetic dilates the pupil, widens the palpebral fissure, and in animals causes proptosis, it increases the rate of the heart and the conductivity of the auriculo-ventricular bundle; it constricts most blood-vessels, especially those of the skin and of the splanchnic viscera, but dilates the coronary arteries and causes contraction of the spleen, it thus causes a rise of blood-pressure and an increased blood-flow, especially through the heart, lungs, brain, and muscles, it inhibits peristalsis in the alimentary canal and promotes contraction of some at least of the sphincters; it is inhibitory to the detrusor muscles of the bladder and is motor to the sphincter; it causes erection of the hairs of the skin and sweating; it excites the secretion of adrenaline, which, by stimulating the sympathetic nerve-endings, in turn reinforces sympathetic action and also raises the blood-sugar by liberating sugar from the liver.

The parasympathetic, on the other hand, constricts the pupil, retards the heart and diminishes conductivity in the auriculo-ventricular bundle, dilates the blood-vessels, at least in certain situations, constricts the bronchioles, excites the secretion of saliva, promotes peristalsis and inhibits the action of some at least of the alimentary sphincters, promotes contraction of the bladder and relaxation of its sphincter, through the nervi erigentes plays the principal part in sexual activity, and excites secretion of insulin, which lowers the blood-sugar.

The antagonism between the sympathetic and the parasympathetic has been stressed especially by Cannon, who points out that the changes produced by sympathetic stimulation are an appropriate preparation for violent activity. The sympathetic has thus been described as an activator for flight or fight, while the parasympathetic presides over anabolic, excretory, and reproductive activities. This is a suggestive generalization, though in some respects it over-simplifies the facts.

Pharmacology.

Numerous drugs influence the autonomic nervous system, though their action is often not strictly selective of either the sympathetic or the parasympathetic.

Adrenaline augments the action of the sympathetic by stimulating its nerve-endings. In very small doses, however, adrenaline may produce vasodilatation instead of vasoconstriction. *Ephedrine* has a similar action to adrenaline, which has been attributed in part to its diminishing the removal of adrenaline. *Ergotoxine* and *ergotamine* inhibit the normal effects of adrenaline. The action of these drugs, however, is often slight. *Pilocarpine* produces the effects of stimulation of the parasympathetic, but in addition causes sweating, which is excited by the sympathetic. *Acetyl-choline* also stimulates the parasympathetic, and *physostigmine* (eserine) and *prostigmin* produce a similar result by inhibiting the breakdown of acetyl-choline. *Atropine* paralyses the parasympathetic and at the same time inhibits sweating. *Nicotine* acts upon the autonomic ganglion cells. In small doses it causes stimulation of both sympathetic and parasympathetic; in large doses paralyses both.

METHODS OF INVESTIGATING THE AUTONOMIC NERVOUS SYSTEM

The investigation of the autonomic nervous system may be necessary when this part of the nervous system is itself the site of disease or as an accessory method of localizing lesions of the central nervous system. The functions of the autonomic nervous system are at present investigated almost exclusively in respect of its influence upon the skin, especially upon (1) the smooth muscles of the skin, (2) its blood-vessels, and (3) sweating.

(1) The Pilomotor Reflex.

Stimulation of the sympathetic fibres innervating the skin causes erection of the hairs and the formation of goose-flesh as a result of contraction of the cutaneous smooth muscles. These phenomena, known as the pilomotor reflex, can be elicited as a local reaction which is the normal response to a stimulus of moderate intensity, for example, a scratch with a pin. A more massive stimulus, however, for example, pinching the cervical region, tickling or scratching the axilla, or the application of cold, by means of a block of ice or wool soaked in ether, to the axilla or to the abdominal wall, is followed by a pilomotor response which extends to the whole of the same half of the body. The pilomotor reflex takes from a quarter to half a minute to develop and persists for a minute or two.

(2) Vasomotor Reactions.

Stimulation of the sympathetic causes constriction of the cutaneous blood-vessels and these are normally maintained in a state of tonic partial contraction by the sympathetic. Interruption of the sympathetic fibres to the skin, therefore, leads to vasodilatation and

flushing, as a result of which the temperature of the denervated area becomes higher than that of the corresponding area on the normal side, and after both local and general exposure to cold the temperature of this area falls more slowly and rises more rapidly than normally. The differences of temperature involved are often small and require special methods of thermometry for their determination, for example, the use of a thermo-couple or of a platinum-resistance skin thermometer. To estimate the part played by the sympathetic in disorders characterized by ischaemia of the extremities the influence of the sympathetic may be temporarily removed by blocking the peripheral nerves with novocain, or, in the case of the lower limbs, by spinal anaesthesia, the cutaneous temperature being recorded before and after this procedure.

Dermo-graphism. The response of the skin to light pressure is local blanching, a direct constrictor reaction of the local capillaries A more vigorous stimulus, such as firm scratching, evokes a triple reaction (Lewis)· (1) a local red reaction along the line of pressure, (2) a spreading flush or 'flare', developing after an interval of about half a minute and extending usually from one to three centimetres on either side of the scratch, and (3) in susceptible persons, or after a very vigorous stimulus, a wheal. The red line (1) occurs independently of the nervous system, but the flare depends upon an axone reflex utilizing the cutaneous sensory nerves, and disappearing when these have degenerated It is to some extent antagonized by the vasoconstrictor influence of the sympathetic, and tends to be exaggerated over areas in which the influence of the sympathetic is diminished.

(3) Sweating.

Sweating can be elicited reflexly in response to cutaneous stimuli to a variable extent in normal individuals. It is best investigated by exposing the patient to radiant heat, by the administration of 20 grains of aspirin, or by the injection of 1/6th to 1/3rd of a grain of pilocarpine nitrate in 1 c.c. of water. Profuse sweating is readily seen, but to detect slight amounts it is necessary to apply a strip of filter paper dipped in an alcoholic solution of cobalt blue and well dried. *This turns pink when moistened with sweat. Sweating is absent over cutaneous areas to which the peripheral sympathetic nerve-supply has been interrupted.*

LESIONS OF THE PERIPHERAL SYMPATHETIC NERVES

The extent of an area of peripheral sympathetic denervation is detected by the *absence of the pilomotor reflex and of sweating,* and by the presence of the temperature changes already described.

2. DISTURBANCES OF THE FUNCTIONS OF THE AUTO-NOMIC NERVOUS SYSTEM AFTER LESIONS OF THE SPINAL CORD

The difference in the distribution of the sympathetic and somatic nervous outflow from the spinal cord accounts for the occurrence in many cases of a difference in the distribution of the sympathetic and somatic (motor and sensory) disturbances after lesions of the spinal cord. Since the sympathetic outflow to the whole body leaves the cord below the eighth cervical spinal segment, lesions at and above this level may cause a disturbance of sympathetic function over the whole body, though the motor and sensory innervation of the head and neck and of a part of the upper limbs remains undisturbed. At the mid-dorsal level of the cord the upper levels of the sympathetic and somatic disturbances approximately coincide. When the lesion of the cord is situated below the first lumbar spinal segment the somatic innervation is alone affected, the sympathetic outflow leaving the cord entirely above the lesion. The following disturbances of sympathetic function are found in cases of complete transection of the cord and in cases of less severe lesions which interrupt the intraspinal paths of the sympathetic. The pilomotor reflex elicited by a massive stimulus applied to the skin above the level of the lesion does not extend to areas innervated by parts of the cord below the lesion, but the reflex is excitable from these regions after the disappearance of spinal shock. The cutaneous temperature over the paralysed parts is higher than over normal parts of the body and vasoconstriction in response to exposure of the whole body to cold is diminished below the level of the lesion. Dermographism is diminished at the level of the lesion but usually somewhat increased below. (See also section on Compression of the Spinal Cord, p. 628.)

Sweating.

Excessive sweating usually appears after complete division of the spinal cord over parts of the body which are thus separated from the control of higher autonomic centres. Such sweating develops *pari passu* with the recovery of other reflex functions in the divided cord. It varies in intensity from time to time and may be reflexly excited by cutaneous stimuli, flexor spasms of the lower limbs, distension of the bladder, and exposure to heat.

Disturbances of sweating are rarely observed after partial lesions of the spinal cord, except in syringomyelia. In this disease loss of sweating may occur when the sympathetic ganglion cells in the

lateral horns of grey matter are destroyed, and is most often seen over the face and upper limb. Excessive sweating with a similar distribution may, however, occur, sometimes spontaneously and sometimes being excited reflexly when the patient takes hot or highly seasoned food.

3. THE AUTONOMIC NERVOUS SYSTEM AND PAIN

Referred Pain.

Since most viscera are innervated only by the autonomic nervous system, it follows that the sensation of visceral pain must be mediated by afferent autonomic fibres. The most potent cause of visceral pain is an increase in the tension of the viscus. Visceral pain is a diffuse and poorly localized sensation and is frequently associated with pain referred to, and tenderness of, the superficial tissues of the body over an area which is innervated by the same segments of the nervous system as the painful viscus. The physiological explanation of referred pain is uncertain, but it may be due to a heightened excitability of the central fibres concerned in pain-conduction, which receive *impulses from the segments innervating the viscus.* Since most viscera receive a double nerve-supply, both sympathetic and parasympathetic, both of which may conduct painful impulses, a visceral lesion, as Head showed, may be associated with two areas of referred pain. The area of reference corresponding to innervation through the sympathetic nervous system involves one or more spinal segments. When the viscus is also innervated by *the vagus, the area of referred pain is found within the distribution* of the trigeminal or upper cervical areas which constitute the somatic sensory distribution corresponding to the vagus. Individuals differ greatly in their susceptibility to referred pain and the extent of the area of reference varies from time to time in the same individual in correspondence with the state of the viscus. One of the commonest examples of referred pain is that associated with disease of the coronary arteries, such as occurs in angina pectoris. In angina, pain is usually referred into the third, fourth, and fifth cervical and first, second, and third dorsal segments on the left side and often into the same or a somewhat similar area on the right side. The corresponding area in the trigeminal distribution extends on to the forehead and cheek around the eyes.

Segmental Areas corresponding to the Viscera.

Pain from diseases of the eyes, nasal sinuses, middle ear, teeth, tongue, tonsils, and larynx is referred into areas within the distribu-

tion of the trigeminal and upper cervical nerves. The following are the spinal segments into which pain is referred in diseases of the thoracic and abdominal viscera (Head):

Viscus	Spinal Segments
Lungs	1–7 dorsal, mostly 2–5 dorsal
Heart	3–5 cervical, 1–8 dorsal, predominantly on left side, sometimes bilateral
Oesophagus	mainly 5 dorsal, also 6, 7, and 8 dorsal
Breast	4 and 5 dorsal
Stomach	7, 8, and 9 dorsal, usually bilateral
Intestine	9–12 dorsal, bilateral or on left side only
Liver	8–10 dorsal on right side
Gall bladder	mostly 8 and 9 dorsal, also 5–7
Kidney	mostly 10 dorsal, also 11 and 12 dorsal and 1 lumbar
Ureter	11 and 12 dorsal and 1 lumbar
Testis	10 dorsal
Epididymis -	11 and 12 dorsal
Bladder	11 and 12 dorsal and 1 lumbar, also 3 and 4 sacral
Prostate	10 and 11 dorsal, also 1–3 and 5 sacral
Ovary	10 dorsal
Fallopian tubes	11 and 12 dorsal
Uterine cervix	11 and 12 dorsal and 1–4 sacral
Uterine body	10 dorsal to 1 lumbar.

The following are the principal areas of referred pain on the scalp corresponding to spinal segmental areas of reference:

Cervical 3 and 4	Fronto-nasal	Dorsal 8	Vertical
Dorsal 2 and 3	Mid-orbital	Dorsal 9	Parietal
Dorsal 5 and 6	Fronto-temporal	Dorsal 10	Occipital
Dorsal 7	Temporal		

The autonomic nervous system sometimes provides an alternative path for painful sensations from areas deprived of their somatic sensory nerves. When pain can be evoked in such circumstances the painful impulse is probably conducted to the central nervous system by the autonomic nerves supplying the blood-vessels. Autonomic painful impulses have been held responsible for some forms of neuralgia, especially in the face, but the interruption of the cervical sympathetic in such conditions has yielded uncertain results.

4. AUTONOMIC AND METABOLIC CENTRES

Anatomy.

Recent researches have shown that the autonomic nervous system and many metabolic functions are under the control of nerve-centres, many of which are situated in the hypothalamus. This is the region of the brain lying ventrally to the thalamus and constituting the floor of the third ventricle. The most important part of the hypothalamus is the tuber cinereum, which forms part of the floor of the third ventricle and extends from the optic chiasma anteriorly to the corpora mamillaria behind. In the centre of the tuber is the infundibulum, from which rises the stalk of the pituitary body. The hypothalamus contains a large number of scattered ganglion cells, which have been differentiated into a number of nuclei. The nuclei themselves are arranged in three groups and there is some evidence that a functional differentiation corresponds to this anatomical arrangement. The following are the principal nuclei of the preoptic area and the hypothalamus (Le Gros Clark, 1938):

| Preoptic Area . | . | Medial Preoptic nucleus. |
| | | Lateral Preoptic nucleus. |

Hypothalamus——
Pars Supraoptica

Hypothalami	.	Nucleus Supraopticus.
		Nucleus Paraventricularis.
		Nucleus Suprachiasmaticus.

Nucleus Hypothalamicus Anterior.

Pars Tuberalis

Hypothalami	.	Nucleus Hypothalamicus Dorsomedialis.
		Nucleus Hypothalamicus Ventromedialis.
		Nucleus Arcuatus.
		Nucleus Hypothalamicus Lateralis.

Nucleus Hypothalamicus Posterior.

Pars Mamillaris

Hypothalami	.	Nucleus Mamillaris Medialis.
		Nucleus Mamillaris Lateralis.
		Nucleus Intercalatus.
		Nucleus Premamillaris.
		Nucleus Supramamillaris.

The projections of the hypothalamus are not yet completely known. The following tracts, however, are probably of special importance. From the supraoptic nucleus arises a tract which terminates in the

pars intermedia and the pars posterior of the pituitary. The fornix system runs from the hippocampus to the mamillary region and the mamillo-thalamic tract (bundle of Vicq d'Azyr) runs from the mamillary body to the anterior nucleus of the thalamus. There are also both efferent and afferent tracts running between the mamillary body and the mid-brain.

The hypothalamus is richly supplied with blood from the vessels of the circle of Willis.

The Functions of the Hypothalamus.

The functions of the hypothalamus have been investigated by means of stimulation and experimental lesions. The posterior and lateral hypothalamus is an important centre for the activity of the sympathetic nervous system. Stimulation of the posterior hypothalamus causes an increase of the heart-rate, rise of blood-pressure, dilatation of the pupil, erection of the hair, and inhibition of movements of the gut and of the tone of the bladder. The nuclei of the posterior hypothalamus are also responsible for the massive reaction known as 'sham rage' which occurs in animals when this region has been released from higher control.

The nuclei of the tuber, on the other hand, appear to be concerned with the functions of the parasympathetic. Stimulation of this region causes slowing of the heart-rate and increase in the auriculoventricular conduction time. There is also an increase in the peristaltic movements of the stomach and of the tone of the bladder. Lesions of this region may cause haemorrhagic erosions of the mucosa of the body of the stomach. *Adiposo-genital dystrophy, characterized by great obesity and genital atrophy*, may be produced by experimental lesions of the tuber.

The anterior group of nuclei are of interest in relation to water metabolism. Diabetes insipidus, which since the work of Camus and Roussy and Bailey and Bremer has been known to follow lesions of the hypothalamus, is now regarded as the result of damage to the supraoptic nuclei which are linked with the pituitary as described above. After lesions of these nuclei the posterior lobe of the pituitary degenerates. It is believed that this causes the withdrawal from the circulation of an antidiuretic pituitary hormone the action of which is possibly central, i.e. upon one or other of the tuber nuclei (Biggart, 1935). There are still obscurities, however, in the causation of diabetes insipidus, especially with regard to the role of the anterior lobe of the pituitary, the presence of which is believed to be necessary in order that polyuria may occur.

The hypothalamus is also concerned with the regulation of the temperature of the body in which shivering, sweating, vaso-constric-

tion, and vaso-dilatation as well as other factors play a part. The role of the hypothalamus in carbohydrate metabolism is not completely understood, but glycosuria, which is usually transitory, may follow lesions of this region. The hypothalamus is also concerned in sleep regulation (see p. 826).

5. SYNDROMES OF THE HYPOTHALAMUS

1. Diencephalic Autonomic Epilepsy.

Penfield has employed this term to describe attacks of disturbance of the function of the autonomic nervous system, which appear to be due to neural discharge from centres in the hypothalamus In Penfield's patient, after a prodromal phase of restlessness, there was flushing of the skin of the face, together with a rise of blood-pressure, lacrimation, sweating, salivation, dilatation or contraction of the pupils, protrusion of the eyeballs, increase in the pulse-rate, retardation of the respiratory rate, and in some attacks loss of consciousness; hiccup occurred towards the end of the attack. This patient had a tumour of the third ventricle with internal hydrocephalus. Similar attacks occurred in a patient of my own in whom the lesion was a tumour of the left hemisphere which had extensively invaded the mid-brain.

The 'vaso-vagal' attacks of Gowers appear also to be paroxysmal discharges of the autonomic nervous system.

2. Adiposity.

Adiposity, which is generally associated with genital hypoplasia or atrophy, may occur as a symptom of a variety of pathological states involving either the hypothalamus or the pituitary, or both of these structures.

(i) *Chromophobe adenoma of the pituitary* may produce it (see p. 255).

(ii) *Suprapituitary tumour*, especially hypophyseal epidermoid tumours (see p. 258).

(iii) *Internal hydrocephalus* from any cause may lead to obesity and genital hypoplasia as a result of distension of the floor of the third ventricle which compresses the sella turcica and the pituitary. In this way the syndrome may result from a tumour remote from the sella turcica, for example, a tumour of the cerebellum.

(iv) The syndrome may be produced by *infective conditions of the nervous system*, especially by encephalitis lethargica and, rarely, basal syphilitic meningitis.

(v) *Idiopathic adiposo-genital dystrophy*. In the majority of cases of this syndrome, including those in which the disturbance of function

is most marked, none of the above causes can be held responsible. The disorder appears to be present from birth, and it is usually noticed at an early age that the child is exceptionally fat. Both sexes are affected, though boys appear to suffer more often than girls.
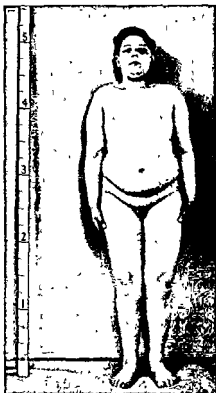
FIG 75. Adiposo genital dystrophy in a boy aged 11; weight, 12st. 4lb.

The Hebrew race appears exceptionally liable. Obesity is the most conspicuous abnormality, and the fat is most evident around the shoulders and hips (Fig. 75). The fingers are usually fine and tapering. The cheeks are rosy, and the skin is soft and hairless, except on the scalp. In these cases obesity is often associated with skeletal overgrowth, the child being exceptionally tall as well as exceptionally fat. Knock-knee is usually present, probably as a result of the weight. There is often a marked genital hypoplasia, though exceptionally genital function may be normal. This is the case more often in females than in males. Sugar tolerance is usually increased. Polyuria, lethargy, and narcolepsy are exceptional associated symptoms. There is no evidence of a lesion involving the visual paths and the sella turcica is radiographically normal. These negative findings, together with the early onset, render it possible to distinguish the idiopathic variety of adiposo-genital dystrophy from other conditions of which similar disturbances are symptomatic.

(vi) *The Laurence-Moon-Biedl Syndrome*. This unusual syndrome, first described by Laurence and Moon in 1866, is characterized by obesity, hypogenitalism, mental retardation, polydactyly, and retinal pigmentation. Cockayne, Krestin, and Sorsby (1935) stated that 30 isolated cases and 15 affected families were reported during the 10 years 1925 to 1935. The familial occurrence points to an inherited

predisposition as the cause, and various genetic theories have been proposed to explain the disorder. The most satisfactory is that which regards it as being inherited as an autosomal recessive, the epiblastic and mesoblastic abnormalities being attributed to two separate abnormal genes carried in the same chromosome. Males are affected more often than females.

Little is known about the pathology, but Griffiths (1938) has described the pathological changes in one case, consisting of fibrosis of the thymus, reduction in size of the pituitary, with excess of basophil and diminution of eosinophil cells, and hypoplasia of the uterus and ovaries. The brain showed frontal atrophy and an abnormally small number of cells in the nuclei of the tuber. The adiposo-genital dystrophy may well be hypothalamic in origin

The symptoms show some variability from family to family. The retinal pigmentation is usually that of typical retinitis pigmentosa, but other forms are seen. Vision suffers severely. Coloboma of the iris has also been described. The number of digits is six, but on either the hands or the feet the supernumerary digits may be represented by buds, only visible by X-rays. The mental defect is not usually gross, and there is nothing distinctive about the adiposo-genital dystrophy. Van Bogaert and Borremans (1936) have described hyperostosis of the frontal bones as an additional symptom. The combination of frontal hyperostosis and obesity is a feature common to both the Laurence-Moon-Biedl syndrome and Morgagni's Syndrome (see p. 842).

Treatment.

When adiposo-genital dystrophy is due to tumour or encephalitis the causal condition must receive appropriate treatment. Treatment of the idiopathic variety is usually disappointing, but there is a tendency for improvement to occur after the normal age of puberty. Thyroid extract is often administered, but usually has little or no effect. The use of pituitary extracts would seem to have a more rational basis, but has proved disappointing. A diet in which fats and carbohydrates are rigidly restricted will usually reduce the weight or at least retard its increase.

3. Cachexia.

Cachexia is much less frequently encountered as a symptom of a lesion of the hypothalamus than obesity. It is occasionally produced, however, by suprasellar tumours and is common in the advanced stages of Parkinsonism due to encephalitis lethargica.

4. Sexual Functions.

Failure of the sexual functions to develop at the normal age, or retrogression after normal development, may be the result of lesions

either of the hypothalamus or of the pituitary. Sexual infantilism, or, in the adult, impotence or amenorrhoea, according to sex, is usually associated with obesity as described in the last section.

Sexual precocity is much rarer. It may be a symptom either of endocrine or of nervous disorder. In the endocrine sphere it may be produced by tumours of the ovary, testis, or suprarenal. Pineal tumours cause sexual precocity in a proportion of cases, almost exclusively in males, but sexual precocity may also be produced by other tumours of the mid-brain and by hydrocephalus from any cause. It has also been reported after encephalitis lethargica and in association with tuberous sclerosis and suprasellar tumours as well as in rare cases of glioma of the hypothalamus.

So far we have been considering bodily changes in the reproductive organs resulting from disease of the nervous system. Loss of sexual desire without concurrent bodily change is not uncommonly encountered in patients with a tumour involving the base of the brain and sometimes occurs after head injury and in association with extensive destructive cerebral lesions of any kind. Excessive libido, on the other hand, may be experienced by patients in whom a tumour or a more diffuse lesion, such as general paralysis in an early stage, diminishes inhibition.

Impotence implies a condition in the male in which sexual desire is normal but the patient cannot achieve an erection of the penis adequate for sexual intercourse. Erection of the penis and ejaculation of semen depend in the first instance upon the integrity of reflex arcs at the sacral level of the spinal cord. Injury to these reflex arcs, such as may occur in tabes, spina bifida, or a tumour of the corda equina, may cause impotence. Since, however, higher centres also play a part in the sexual act, impotence may be produced by lesions of the spinal cord at a higher level, as, for example, in disseminated sclerosis. If the nervous system is normal and there is no debilitating general disease impotence is neurotic in origin. Simple anxiety may cause impotence which may be associated with ejaculatio praecox, which is explained by the fact that the sympathetic nervous system, which is over-active during anxiety, is inhibitory to erection of the penis but motor to the vesiculae seminales. Often, however, the cause of neurotic impotence lies deeply in the personality and can only be exposed by psychological analysis.

5. Diabetes Insipidus.

Diabetes insipidus is occasionally hereditary; but usually occurs sporadically as a result of lesions involving either the tuber cinereum or the pituitary, though in the latter case the polyuria is usually less severe than in the former. Tuberal lesions responsible for diabetes

insipidus include trauma, ranging from gun-shot wounds of the supra-pituitary region to comparatively mild blows on the head, basal meningitis, which is usually syphilitic, epidemic encephalitis, cerebral malaria, and tumours of the third ventricle, and the syndrome may also be produced by primary and secondary neoplasms and tuberculoma of the pituitary (for its physiology see p. 818)

Diabetes insipidus forms an integral part of the rare and remarkable syndrome—diabetic exophthalmic dysostosis (see p. 839).

Diabetes insipidus causes extreme thirst and the passage of large volumes of urine, amounting in severe cases to several gallons a day *Sleep is disturbed by thirst and the necessity for frequent micturition.* Bulimia is a rare accompaniment.

The prognosis of diabetes insipidus is considerably influenced by the nature of the causative lesion. Polyuria following encephalitis lethargica is rarely severe. There are often marked fluctuations in the urinary output from day to day, and spontaneous recovery may occur. In syphilitic cases benefit may follow antisyphilitic treatment When the cause is tumour, relief may follow if this can be removed.

Prognosis in traumatic cases is uncertain. Some patients improve or recover after a few months: in others the disorder is permanent

In severe cases extract of the posterior lobe of the pituitary affords the only palliative treatment. Nasal insufflation of posterior lobe extract may be tried but is often ineffective. Gauze tampons soaked in pituitrin may be placed in the nostrils. Usually it is necessary to inject $\frac{1}{2}$ to 1 c.c. of pituitrin subcutaneously to obtain a few hours' relief from the polyuria and thirst. It may be necessary to give more than one dose during the day If one dose only is given, it should be administered at bedtime, in order to ensure several hours' sleep. Rarely pituitrin is ineffective.

6. Disturbances of Sleep.

The role of the hypothalamus in the normal regulation of sleep is still uncertain, but clinical experience shows that lesions in the *region of the tuber cinereum* may lead either to persistent somnolence or to paroxysmal attacks of sleep—narcolepsy (see p. 826).

7. Other Hypothalamic Disturbances.

Sugar Metabolism.

The disturbances of sugar metabolism which have been produced by experimental lesions of the hypothalamus find a clinical counterpart in the occurrence of glycosuria as a result of lesions of this part of the brain. Glycosuria is most often seen in patients with a tumour in the region of the hypothalamus or the fourth ventricle. It is more often due to a lowered renal threshold than to hyperglycaemia.

'Cerebral glycosuria' may also occur after head injury and spontaneous subarachnoid haemorrhage and in meningitis and encephalitis lethargica.

Temperature Regulation.

Irregular pyrexia may occur in patients with a lesion in the region of the tuber cinereum, and the hyperpyrexia which not uncommonly follows operations in this region is probably the result of injury to a hypothalamic temperature-regulating mechanism.

Ulceration of the Alimentary Canal.

Many years ago Schiff demonstrated that lesions in the neighbourhood of the hypothalamus were followed by acute ulceration of the upper part of the alimentary canal, and this has since been confirmed. Perforating ulcers may thus be produced in the oesophagus, stomach, and duodenum of experimental animals. Cushing has drawn attention to the occurrence of similar ulceration in man, as a rare sequel of cerebral operations, and it may also follow operation on the spinal cord.

Respiratory Disturbances.

There is evidence that abnormalities in the rate and amplitude of respiration may be produced by lesions of the hypothalamus, and it is probable that this is the explanation of the respiratory disturbances which have sometimes been seen as sequels of encephalitis lethargica.

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6. SLEEP AND ITS DISTURBANCES

The Nature of Sleep

The rhythmically recurring physiological loss of consciousness of which sleep consists involves changes of function in all the organs of the body Earlier views of the nature of sleep sought to explain it in terms of functional changes which are probably rather its results than its causes. There are now few to maintain that sleep is primarily the result of a change in the circulation of blood or of its chemical composition, nor is there much more to be said for the view that it is the direct result of changes in endocrine secretion. The existence of fatigue toxins remains hypothetical.

Increasing knowledge of the physiology of sleep and of the nature of its disorders has led to stress being laid upon the neural aspect of sleep. The rapid onset and cessation of sleep, and particularly its disorders, such as narcolepsy, point to a change of neural function as its basis.

Sleep as Inhibition.

The idea that inhibition is an important element in sleep, though by no means new, was elaborated by Pavlov, who considered that the state of the cerebral cortex during sleep was identical with inhibition because he observed during his experiments on the production of conditioned reflexes that an animal was liable to fall asleep during a phase of the reflex in which he considered that inhibitory processes were active. Sleep, therefore, according to Pavlov, is widespread cortical inhibition. This identification, however, is open to question on the ground that the fact that sleep may coincide with a process of inhibition does not necessarily mean that the two are identical.

The Sleep-Waking Centre.

There is both experimental and clinical evidence for the existence of a centre concerned with the regulation of sleep and waking, situated in the posterior part of the hypothalamus. It has repeatedly been shown that lesions in this region, especially between the corpora mamillaria and the nucleus of the third nerve, and involving the efferent paths from the hypothalamus, cause pathological somnolence in animals. Lesions produced in man by disease, being more diffuse, are of less localizing value, but the sleep disturbances characteristic of epidemic encephalitis lethargica can be correlated with the predilection of the virus of this disease for the grey matter around the anterior end of the aqueduct of Sylvius and intracranial tumours are most likely to produce somnolence when they are situated in the interpeduncular space. Since destruction of this region causes

somnolence, it would, perhaps, be more aptly described as a waking centre rather than as a sleep centre.

Its mode of action is not understood. The suggestion has been made that since consciousness depends to a considerable extent upon incoming stimuli transmitted to the brain from the sensory receptors, the interruption of afferent impulses reaching the cerebral cortex may be an important element in the onset of sleep. Bremer states that in an animal decerebrated by transection of the brain stem the electro-encephalogram of the cerebral cortex is identical with that during normal sleep.

The Electro-encephalogram during Sleep.

Several workers have studied the changes of electrical potential which occur in the cerebral cortex during sleep by means of electro-encephalography. Briefly, as sleep deepens there is a transition from normal alpha waves through a phase of bursts of more rapid waves to the development of slow random waves. Dreams have been shown to be associated with a burst of alpha waves in the second stage of sleep. Fat solvent anaesthetics also produce characteristic changes and during deep ether and chloroform narcosis large, slow, rhythmic waves over the whole cortex are recorded at a rate of two to three a second and a magnitude of several hundred microvolts. Barbiturates, however, such as evipan, cause a large discharge over the whole cortex with a rate of about eight per second, which has been interpreted as indicating an interruption of afferent sensory pathways. Bremer states that barbituric sleep is electro-encephalographically identical with normal sleep.

While it is probable that all levels of the nervous system are involved in sleep, it seems likely that a change of cortical function is the essential feature and that normal sleep is the product of an interplay between the cortex and the hypothalamic sleep-waking centre.

Bodily Changes during Sleep.

During sleep not only is consciousness lost, but certain bodily changes occur. The pulse-rate, blood-pressure, and the respiratory rate fall; the eyes usually deviate upwards, the pupils are contracted, but continue to react to light, though slowly; the tendon reflexes are abolished and the plantar reflexes may become extensor.

PATHOLOGICAL SLEEP

There are two abnormal forms of sleep, narcolepsy and hypersomnia. Narcolepsy is sleep which is abnormal by reason of its onset's being irresistible, though the circumstances may be inappropriate and excessive fatigue is absent. The patient can be aroused

from the narcoleptic attack than from normal sleep. Hypersomnia may be defined as sleep which is abnormally prolonged and from which it is more than normally difficult to arouse the patient.

NARCOLEPSY

It is necessary to consider with narcolepsy four other forms of sleep disturbance which, since they may be associated with narcolepsy or with each other in the same patient, are closely related to one another. These are cataplexy, sleep paralysis, hallucinatory states associated with sleep, and somnambulism. The first case of narcolepsy was described by Westphal in 1877, but the term 'narcolepsy' was first used by Gelineau (1880).

Narcolepsy.

The irresistible attacks of sleep characteristic of narcolepsy may be very numerous, occurring many times a day. In the *attacks the patient suddenly becomes unconscious and the condition resembles normal sleep in that he can be aroused immediately by appropriate stimuli*. The attacks are most likely to occur in circumstances normally conducive to drowsiness, such as after a heavy meal or during a monotonous occupation, especially when driving a car. They are usually worse in the afternoon. They are occasionally precipitated by strong emotion. The sleep is usually brief, lasting only for seconds or minutes, but if the patient remains undisturbed he may sleep for hours.

Cataplexy.

By cataplexy is understood an attack to which sufferers from narcolepsy are liable, but which differs from sleep in that, though the patient suddenly loses all power of movement and of maintaining posture, consciousness is preserved. Sometimes tremor of the head or muscular twitching occurs at the onset, but these may be absent. The patient sinks limply to the ground with the eyes closed. The muscles are hypotonic, the pupils may fail to react to light, the tendon reflexes may be diminished or lost, and during the attacks the plantar reflexes may be extensor. Though completely unable to move or to utter a sound, the patient is fully aware of all that is happening. Cataplectic attacks usually last less than a minute and recovery is rapid. They are commonly precipitated by strong emotion, pleasurable or otherwise, especially by laughter, and the patient may be unable to move until he has controlled his emotion.

Sleep Paralysis.

Sleep paralysis resembles cataplexy except that instead of being precipitated during the day by emotion, it usually occurs during

the period of falling asleep or of awakening The patient, though fully conscious, is unable to move hand or foot and often experiences intense anxiety. A touch will rapidly disperse the paralysis.

Hallucinatory States associated with Sleep

Sufferers from narcolepsy sometimes experience vivid hallucinations. These, which are more often visual than auditory, may occur as the patient is falling asleep, when they are termed hypnagogic hallucinations. Sometimes, however, they occur during the night, when the patient is apparently awake These hallucinations are often elaborate and terrifying, and though they seem real at the time their true character is readily recognized during normal waking life. The night terrors of childhood appear to be of a similar nature.

Somnambulism.

Somnambulism may be regarded as the reciprocal of cataplexy in that the patient, though partly asleep, is able to stand and walk in an automatic fashion It is occasionally associated with narcolepsy, but usually occurs in adolescents of a neurotic disposition but otherwise normal.

The Nature of Narcolepsy and Allied Disorders.

Some authors—for example, Wilson—have thought that narcolepsy is allied to epilepsy Adie, however, and others have put forward the view that it is a disturbance of sleep. This is supported by the fact that narcoleptic subjects, as has already been shown, are liable to various disturbances of their nocturnal sleep. Narcolepsy, on this hypothesis, is to be regarded as sleep of sudden and irresistible onset, and cataplexy as a localized sleep affecting the centres concerned in movement and posture only. Sleep paralysis is the outcome of a failure of the uniform spread of sleep over the nervous system, the levels concerned with consciousness remaining awake when the motor and postural levels have fallen asleep, or, conversely, awakening before them. The hallucinatory states appear to be the product of a dissociation of consciousness, akin to dreaming, when the subject *is partially awake ; and somnambulism, the converse of cataplexy,* is a condition in which the highest levels are asleep, but lower levels are awake.

The Causes of Narcolepsy.

Narcolepsy may be symptomatic or idiopathic. Symptomatic narcolepsy may follow head injury or may be due to cerebral arteriosclerosis, neurosyphilis, encephalitis lethargica, or intracranial tumour involving the posterior part of the hypothalamus. In such cases it is probably due to disturbance of function of the sleep

centre. More often no cause can be found and the disorder is then designated idiopathic narcolepsy. Males are more subject to this than females and the onset usually occurs during adolescence or, at any rate, under the age of thirty. *Idiopathic narcolepsy is probably in many instances in the true sense a functional disorder, that is, a disturbance of function consisting of an exaggeration of a normal tendency to drowsiness.* Physical abnormalities indicative of disorder of other functions of the hypothalamus may be present, especially obesity, with or without genital atrophy.

Diagnosis.

Both narcolepsy and cataplexy are so distinctive that diagnosis usually presents no difficulty. Narcolepsy is distinguished from both epilepsy and syncope in the circumstances in which the attacks occur *and in that when consciousness is lost the patient can be immediately aroused.* Cataplexy is distinguished from these disorders by the preservation of consciousness. Careful investigation should be made for evidence of organic disease involving the hypothalamus.

Prognosis.

The disorder does not threaten life unless the patient should be unfortunate enough to have an attack in a dangerous situation. The response to treatment is, as a rule, disappointing and the attacks usually continue indefinitely, though occasionally they cease spontaneously. I have known one patient who, after suffering from narcolepsy for twenty years, developed typical epileptic attacks, but this is very rare.

Treatment.

The sufferer *from narcolepsy will necessarily be debarred from occupations in which an attack of sleep may endanger him,* and should not be allowed to drive a car. Ephedrine and benzedrine have a specific action upon both narcolepsy and cataplexy. Benzedrine is usually the more effective and the treatment should begin with 10 milligrams two or three times a day. *To avoid disturbing nocturnal sleep the last dose should not be given later than at tea-time.* When narcolepsy or cataplexy by day are associated with disturbances of nocturnal sleep it is wise to give a nightly dose of a barbiturate, and occasionally a small dose of phenobarbital is helpful in controlling the narcolepsy also.

HYPERSOMNIA

Hypersomnia has already been defined as sleep which is unduly prolonged and from which *it is more than normally difficult to arouse* the patient. The state of the patient suffering from hypersomnia

closely resembles that found in normal sleep. Even at the first glance, the healthy colour, tranquil facies, and quiet, somewhat shallow, breathing distinguish hypersomnia from states of coma in which the functions of the cerebral cortex are more profoundly disordered and not merely in abeyance through the over-activity of natural mechanisms. As in normal sleep, the eyelids are closed, the pupils contracted, and the limbs relatively toneless. The tendon reflexes may be diminished or lost and the plantar reflexes may be extensor. The patient can always be aroused to some extent by vigorous stimulation and when thus aroused may reply rationally to questions and will usually swallow food. When the pathological sleep is deep, however, the response may be very limited, but even so it is more normal than that of a patient in coma. Walter, Griffiths, and Nevin (1939) state that in a case of pathological somnolence due to tumour of the hypothalamus the electro-encephalogram resembled that found in deep natural sleep and could be differentiated from the electro-encephalogram both of ether anaesthesia and of coma due to increased intracranial pressure.

The Causes of Hypersomnia.

Hypersomnia is most frequently due to a lesion in the neighbourhood of the posterior hypothalamus and upper part of the mid-brain As von Economo has pointed out, the predilection of the virus of encephalitis lethargica for this situation explains the lethargy or hypersomnia so characteristic of the acute stage of this disease. Other causes of hypersomnia include focal vascular lesions in this situation, syphilitic basal meningitis, and intracranial tumour Tumours are most likely to cause hypersomnia when they are situated in the neighbourhood of the optic thalamus, third ventricle, or interpeduncular space. Hypersomnia may also be caused by tumours in other situations, however, especially if these give rise to hydrocephalus, which may indirectly disturb the function of the hypothalamus. Other *causes of hypersomnia* include head injury, trypanosomiasis, autotoxic states, such as diabetes and uraemia, and poisoning with narcotic drugs. Hysterical trance may be extremely prolonged, lasting in rare cases for years, but it is doubtful if this should be considered as identical with hypersomnia.

The treatment of hypersomnia is that of the underlying cause. Drugs which antagonize sleepiness include benzedrine, ephedrine, caffeine, and strychnine.

INSOMNIA

The inability to sleep at the normal time for the normal period is a symptom which may be caused by a large number of disturbances.

The following list indicates the principal causes of insomnia and the way in which they operate.

1. *Disturbing stimuli.*
   (a) External, such as noise.
   (b) Bodily states, such as fever, heat, cold, hunger, gastric distension, colonic distension, cough, pain, itching.

2. *Abnormal psychical states,* such as worry, anxiety neurosis, depression, hysteria, toxic confusional states and delirium, mania.

3. *Disordered conditional stimuli.* Conditioned reflexes play some part in bringing about sleep. A change in the normal surroundings may therefore cause wakefulness. Moreover, insomnia may become established as a habit and the surroundings which normally evoke sleep may then become associated with wakefulness.

4. *Toxins acting on the brain.*
   (a) Toxic substances introduced from without, such as tea, coffee, alcohol, tobacco, ephedrine, benzedrine, strychnine.
   (b) Toxins generated within the body, as in infections, uraemia, and hyperthyroidism.

5. *Circulatory disturbances,* such as hypertension, cerebral atheroma, heart failure.

6 *Focal lesions of the sleep centre,* such as encephalitis lethargica, vascular lesions, intracranial tumour, &c.

Treatment.

The first step in the treatment of insomnia is the discovery of its cause. Organic disorders and abnormal mental states must be treated appropriately. When insomnia is a neurotic symptom, or merely the result of the disorganization of a normal habit, simple measures usually suffice. Tea and coffee should not be taken in the evening and the last meal of the day should be light and taken not less than two hours before retiring. A small dose of alcohol is often an excellent soporific, but keeps some people awake. The fear that insomnia tends to cause serious mental illness must be dispelled by reassurance. When the usual surroundings have become associated with sleeplessness a change may be helpful. Various devices are sometimes of value, such as a walk before retiring, a hot bath, a hot drink, and cotton-wool in the ears. The bedside book should be unexciting. When trying to go to sleep muscular relaxation is often extremely helpful, especially if it has been practised under skilled supervision during the day.

Sedative drugs are essential for patients in whom insomnia is secondary to organic disease, pain, or mental disorder. In others they are valuable in order to break the habit of sleeplessness. Such drugs are now legion, but many of the oldest have yet to be improved

upon. The bromides, which, however, are not very reliable alone, may be given in doses of 20 to 30 grains. Bromides may be combined usefully with chloral hydrate, the dose of which is 5 to 30 grams The barbiturates are very numerous, but barbital (veronal) in doses of 5 to 10 grains is still useful. Phenobarbital (luminal, gardenal) in doses of 1 to 3 grains is best used for patients suffering from neurosis or toxic states, either alone or in combination with bromide, phenobarbital sodium being the soluble salt. Sodium barbital (medinal) in doses of 5 to 10 grains in cachet or solution is one of the most popular barbiturates and is, perhaps, especially useful in depressive states. Paraldehyde given in doses of 1 to 3 drachms in capsule by the mouth, or 4 to 8 drachms per rectum in olive oil, is useful for confused and excited patients, especially chronic alcoholics. Sulphonal in doses of 10 to 30 grains is a slowly acting hypnotic which is of value for patients who tend to awaken during the night. It should not be used for long periods

Whatever drug is employed should be given not less than one hour before bedtime and in full doses at first, the dose being gradually reduced later. This can best be done without the patient's knowledge if the drug is given in cachet A patient who is improving may be encouraged to have the dose beside the bed and take it only if he fails to go to sleep. It is often necessary to reassure the sufferer from insomnia that he runs no risk of becoming a drug addict Systematic psychotherapy may be required in refractory cases of neurotic origin

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DISEASES OF THE BONES OF THE SKULL

1. OSTEITIS DEFORMANS

Synonym: Paget's disease.

Definition: A chronic disease of the bones characterized by absorption and new bone formation and leading to enlargement of the skull, deformity of the vertebral column, and bowing of the clavicles and long bones of the extremities, and in some cases to nervous symptoms secondary to the bone changes.

Aetiology and Pathology.

Osteitis deformans is a rare disease of unknown aetiology developing in middle life and affecting both sexes.

Histologically the changes in the bones are those of a rarefying osteitis with secondary new bone formation both beneath the periosteum and on the inner side of the corticalis. The deformities are the result of the softening of the bones. The skull becomes thickened, and the distinction between the inner and the outer tables and the diploë is obliterated. The cranial cavity is increased in breadth and to a less extent in length, but its vertical diameter becomes diminished. The base tends to sink relatively to the region of the foramen magnum, which is supported by the vertebral column. Thickening of the skull also leads to a reduction of the size of the vascular and neural foramina and is thus responsable for symptoms of compression of cerebral hemispheres, cerebellum, and cranial nerves. Similar changes in the bones of the vertebral column lead to kyphosis and reduction in the height of the patient, and sometimes to compression of the spinal cord. The clavicles and the long bones of the limbs may also become softened, thickened, and bowed. Generalized atheroma of the arteries is frequently present.

Osseous Symptoms.

The onset of the disease is insidious, the patient usually complaining first of pains in the head and limbs. The gradual enlargement of the skull necessitates an increase in the size of the hat worn, and the deformities of the spine and long bones are noticed, together with the resulting diminution in height, which in extreme cases may amount to as much as a foot. The enlarged skull favours in the frontal and parietal regions. Affected bones often feel unusually warm to the touch. Radiograms show a characteristic appearance, the thickened bone being mottled and 'woolly'.

Nervous Symptoms.

Mental deterioration and epileptiform attacks may occur as a result of compression of the cerebral hemispheres, and symptoms of cerebellar deficiency have also been observed.

Any of the cranial nerves may be compressed owing to reduction in the calibre of their foramina, the olfactory, optic, and auditory nerves being most often affected. I have seen unilateral optic atrophy, paralysis of one external rectus, and also trigeminal neuralgia occurring as isolated nervous symptoms of osteitis deformans In spite of deformity of the spine associated with vertebral collapse, symptoms of compression of the spinal roots are rare, but compression of the cord itself has been reported in a number of cases and may be associated with cranial nerve lesions, such as optic atrophy. Symptoms of spinal compression are described on p. 624. Retinitis pigmentosa may be present.

Diagnosis.

The diagnosis is readily made by X-ray examination of the bones, and this should always be carried out in middle-aged patients who complain of obscure pains in the head or limbs or exhibit unexplained cranial nerve palsies or paraplegia.

Prognosis.

Osteitis deformans is an extremely chronic and slowly progressive disease. Local sarcoma of bone sometimes occurs as a complication. The associated arterial atheroma may prove fatal, for example by causing coronary thrombosis.

Treatment.

Treatment is unsatisfactory. Analgesics will be required and small doses of thyroid extract mitigate the pain in some cases. Laminectomy is necessary when the spinal cord is compressed.

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2. CRANIOSTENOSIS

Synonyms: Oxycephaly; acrocephaly; turricephaly; tower skull.

Definition: A congenital abnormality of the skull due to premature synostosis of the sutures and characterized by an abnormal shape of the head, exophthalmos, optic atrophy, and symptoms of increased intracranial pressure.

Aetiology and Pathology.

It is generally agreed that craniostenosis is due to premature synostosis of the skull bones. This usually begins in the coronal, sagittal, and lambdoidal sutures, but variations are encountered, and the synostosis may be asymmetrical. It has been attributed to displacement of the centres of ossification towards the sutures. Mann (1937) considers that it is due to a localized arrest of development of the post-optic visceral mesoderm (maxillary process) possibly of atavistic significance. The condition is congenital and sometimes hereditary. Though the sutures are closed, the brain continues to grow at the usual rate. Compensatory enlargement of the skull occurs by means of expansion where the sutures are not united and by thinning of the bone—convolutional atrophy from pressure of the growing brain. The ultimate break-down of this compensatory process leads to the development of symptoms of increased intracranial pressure. The optic atrophy has been attributed to various causes, including compression of the optic nerves by narrowing of their foramina, stretching of the nerves by elongation, pressure upon them by the brain and papilloedema due to increased intracranial pressure. It is probable that different factors operate in different cases, and that the optic nerves may be damaged in more than one of these ways simultaneously. The exophthalmos appears to be due to abnormal shallowness of the orbits.

Craniostenosis is a feature of the acrocephalosyndactyly of Apert, in which oxycephaly is associated with syndactyly, and to the craniofacial dysostosis of Crouzon.

Symptoms.

Since oxycephaly is due to a congenital abnormality, the deformity of the skull may be present at birth, but the patient may not come under observation until other symptoms, such as headache and failing vision, develop, which usually occurs in childhood.

The skull is brachycephalic and dome-shaped, with a high forehead, and there may be flattening of the maxillae or asymmetrical facial deformity. The short upper lip is highly characteristic. The eyes are prominent, and a divergent squint and nystagmus are common

FIG. 76. Craniostenosis, note the shape of the head, the closed sutures, the convolutional thinning and the prognathism.

Papilloedema may be present or optic atrophy, usually of the secondary type, with impairment of vision, which may reach complete blindness. Other symptoms due either directly to the bone changes or indirectly to increased intracranial pressure include anosmia and deafness. The mental state is usually normal. Radiograms of the skull show the premature synostosis of the sutures and compensatory enlargement, with marked and sometimes extreme convolutional thinning of the calvarium, especially in the frontal region (Fig 76)

Cranio-facial Dysostosis.

This disorder, described by Crouzon, is closely related to oxy-cephaly, and is usually hereditary. The forehead recedes to the high, rather pointed vertex—trigonocephaly. There are also hyperplasia of the maxillae and relative prognathism, together with exophthalmos, divergent squint, and in some cases optic atrophy.

Diagnosis.

The condition can usually be recognized at a glance from the shape of the skull. In microcephaly the abnormally small size of the skull is secondary to hypoplasia of the brain and symptoms of increased intracranial pressure are absent. In hydrocephalus the skull is enlarged in all its diameters and its total volume, which in oxycephaly tends to be subnormal, is increased. Oxycephaly is not likely to be confused with intracranial causes of increased intracranial pressure, such as tumour, if attention is paid to the shape of the skull.

Prognosis.

In mild cases compensatory enlargement of the skull may be adequate to prevent the development of symptoms. When, however, headache is present or vision is threatened, no improvement can be anticipated, and the patient's condition is likely to become worse.

Treatment.

Only surgical treatment is effective. Attempts have been made to deal radically with the cause by opening the sutures and paring their edges. The success of this procedure is uncertain, and when the stage has been reached at which surgery is required it is wiser to make a large cerebral decompression to permit the establishment of the normal intracranial pressure. Since in some cases it is possible that the optic nerves are directly compressed in their foramina, radiograms of the optic foramina should be taken, and if they appear to be unusually small their surgical enlargement should be considered. King (1938) has reviewed the surgical treatment and described a new technique.

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3. DIABETIC EXOPHTHALMIC DYSOSTOSIS

Synonym: Schüller-Christian's syndrome, xanthomatosis

Definition: A rare disorder usually occurring in childhood and characterized by diabetes insipidus, exophthalmos, and progressive erosion of bones especially of the membranous bones of the skull by xanthomatous deposits.

Aetiology.

This rare disease was first described by Schüller in 1915 and subsequently by Christian in 1920 and Hand in 1921 The essential feature is a tissue infiltration by xanthomatous masses rich in cholesterol. These are now generally regarded as the products of a disturbance of lipoid metabolism. On this view Schüller's disease is related to Niemann-Pick's disease and Gaucher's disease, though the actual lipoid material differs in all three. The cause of the metabolic abnormality is unknown. The diabetes insipidus is due to invasion of the tuber cinereum and pituitary by xanthomatous material.

Multiple cases in the same family have been recorded only twice Males are affected twice or three times as often as females. In three-fourths of all cases the disease begins during the first decade of life, but it may start as late as the second decade

Pathology.

The xanthomatous infiltration is extremely widespread. The reticulo-endothelial cells stuffed with lipoid material are known as 'foam' cells. Bones are diffusely affected, especially the membranous bones of the skull. The pelvic bones are also a common site. The pituitary and tuber cinereum are commonly invaded by the xanthomatous material and the exophthalmos is produced by xanthomatous masses situated in the orbital fat. Plaques of demyelination containing 'foam' cells have been described in the nervous system by Davison (1933) and Chiari (1933). Xanthomatosis may also be present in the liver, spleen, lymph-glands, lungs, and pleura.

Symptomatology.

Diabetes insipidus leading to polyuria and polydipsia is often the earliest symptom and may occur at a time when there is no radio-

logical evidence of bony change in the skull. It is present in three out of four cases. Exophthalmos is slightly less frequent. Retardation of growth and mental development has been observed in about half of the cases, and adiposo-genital dystrophy is sometimes seen. Gingivitis and falling out of the teeth is not uncommon and there may be a persistent discharge from the ears. The colour of the skin may alter owing to xanthomatous deposits and the liver, spleen, and lymph-glands may be enlarged. The total fat of the blood may be above normal, but the blood cholesterol, calcium, and phosphorus have been found normal.

Radiograms of the skull show large areas of defect in the membranous bones, especially towards the base in the frontal, temporal, and parietal regions. The sella turcica is often, but not invariably, normal. Other bones, especially those of the pelvis, femora, vertebrae, scapulae, and ribs, may also exhibit decalcification. Radiograms of the lungs may show a diffuse mottling resembling miliary tuberculosis with increased density of the hilar shadows.

Diagnosis.

The diagnosis will hardly give rise to difficulty except in those cases in which diabetes insipidus develops before there is any radiographic change in the skull, and in the absence of exophthalmos. In such cases an area of bone destruction will often be found somewhere in the body, particularly in the pelvis.

Prognosis.

The disorder appears usually to be progressive and to terminate fatally, but owing to the small number of cases in the literature it is uncertain whether this is invariably the case.

Treatment.

The polyuria responds considerably to pituitary extract and a temporary improvement in symptoms often follows X-ray irradiation.

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4. GARGOYLISM

Synonym: Hurler's syndrome.

Definition: The term gargoylism has been applied by Ellis, Sheldon, and Capon (1936) to a syndrome first described by Hurler in 1919 and characterized by a peculiar type of osseous dystrophy with congenital clouding of the cornea, enlargement of the liver and spleen, and mental deficiency.

Aetiology.

Little is yet known about the aetiology of this disorder The pathological changes in the nervous system appear to be identical with those of cerebro-macular degeneration, and it has been suggested that gargoylism belongs to the group of disorders characterized by changes in lipoid metabolism. Lipoid changes, however, may be absent in the liver and spleen (Ellis, 1938) The disorder is almost certainly congenital and may be familial.

Pathology.

Very few cases have been studied pathologically. Ballooning of the ganglion cells of the nervous system with lipoid, a change identical with that found in cerebro-macular degeneration, has been described by Tuthill (1934), Ashby, Stewart, and Watkin (1937), and D. S. Russell (personal communication).

The pituitary was enlarged in both the cases of Ashby and his co-workers, and in one the enlargement was due to a general cellular hyperplasia. Hydrocephalus, the cause of which is not yet explained, is often present.

Symptoms.

The bony changes are striking. The skull may be generally enlarged owing to hydrocephalus, and other abnormalities of shape, especially scaphocephaly, are often present. The supra-orbital ridges may be prominent and the bridge of the nose depressed Changes in the base of the skull are probably responsible for the great enlargement of the sella turcica, which has been described in some cases. The mandible is massive and prominent. Kyphosis, due to deformity of the vertebral bodies at the dorso-lumbar junction, is usually

present. The upper extremities are shorter than normal and there is limitation of movement at the joints and almost invariably clawhand. Genu valgum and coxa valga are not uncommon.

The cornea exhibits multiple opacities widely scattered, but situated principally in the deeper layers. Enlargement of the liver and spleen has been found in most cases, but there is a disproportionate degree of abdominal distension usually accompanied by umbilical or inguinal herniae.

All patients appear to be mentally defective and can usually speak little, if at all. No constant biochemical changes have been described.

Diagnosis.

Cretinism may be suggested by the mental deficiency, dull expression, and prominent abdomen, but the bony changes, especially in the skull, are distinctive both from cretinism and from congenital syphilis.

Prognosis.

Insufficient cases have been observed to enable the prognosis to be estimated. Most patients appear to die in childhood, but one at least has reached the age of 19. The condition may certainly remain stationary for long periods.

Treatment.

No effective treatment is known, but some general improvement is said to have followed thyroid administration in one or two cases.

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5. HYPEROSTOSIS FRONTALIS INTERNA

Hyperostosis frontalis interna, or Morgagni's syndrome, is a rare disorder of uncertain aetiology occurring almost exclusively in women and developing during middle life. The disease derives its name from the characteristic thickening of the inner table of the

skull, especially in the frontal region, though it may involve other
bones of the skull also. The inner surface of the thickening is nodular
and it may attain a depth of more than 1 cm. This consists of
spongy bone containing large numbers of osteoblasts, and the under-
lying dura is usually thickened and adherent. Associated symptoms
include obesity, occasionally other endocrine abnormalities such as
diabetes mellitus or insipidus, headaches, and mental disturbances
which range from emotionalism, depression, and impairment of
memory to dementia. The radiographic appearances establish the
diagnosis. Ergotomine tartrate is said to relieve the headache
Surgical removal of affected areas of bone has been carried out.

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CHAPTER XX

PAROXYSMAL AND CONVULSIVE DISORDERS

1. MIGRAINE

Synonyms: Hemicrania; bilious attack; sick headache.

Definition: A paroxysmal disorder characterized in its fully developed form by visual hallucinations and other disturbances of cerebral function, associated with unilateral headache and vomiting.

Aetiology and Pathology.

Migraine has been known to medical science for nearly 2,000 years. In the first century of the Christian era Aretaeus of Cappadocia (A.D. 30–90) described it as heterocrania, and the term hemicrania, from which migraine was derived, was introduced by Galen (A.D. 131–201). Among modern authors Liveing's (1873) is a classic.

The aetiology of migraine is complex and difficult. It is not a fatal disease and pathological investigations are therefore scanty. Moreover, since it appears to be primarily a disorder of function little information is likely to be gained from morbid anatomy.

The Intracranial Disturbance of Function.

On the whole the most plausible hypothetical explanation of migraine is that it is due to arterial spasm followed by dilatation occurring within the distribution of the common carotid artery. On this hypothesis arterial spasm is responsible for the subjective visual disturbances and other cortical symptoms at the onset of the attack, while subsequent vaso-dilatation causes the headache and is manifest in flushing of the face, congestion of the superficial temporal artery and of the conjunctiva and nasal mucosa on the side of the headache. The specific effect of ergotamine tartrate on the headache is attributed to its increasing the tone of the branches of the external carotid artery. Other hypotheses would explain migraine as due to localized cerebral oedema, dilatation of one lateral ventricle due to swelling of the choroid plexus and blockage of the foramen of Munro, or swelling of the pituitary body. Whatever the nature of the intracranial disturbance it is clear that it may be precipitated by more than one other factor and it is probable that in susceptible individuals more than one sort of stimulus may cause an attack, though in different patients different causal factors predominate.

Reflex Factors.

Refractive errors and defective ocular muscle balance are often blamed for migraine, though probably usually with little justification.

Attacks may certainly be precipitated, however, by unusual visual stimuli, especially looking at a bright light. Nasal sinus disease may also cause true migraine as distinct from referred pain.

Allergy.

The importance of allergy has been stressed by Balyeat (1933). Sufferers from migraine may often be shown to be sensitive to one or more food protein and may suffer from other disorders of an allergic nature, most frequently from colon spasm.

Dietetic Factors.

While allergy may explain the precipitation of attacks by protein to which the patient is sensitive, other dietary factors may play a part. Thus the excessive consumption of animal fat or of alcohol may be followed by an attack, so, too, may missing a meal.

The Liver and Duodenal Stasis

There is evidence in support of the old-fashioned view that disturbance of liver function plays a part in the causation of migraine. Sufferers from migraine not uncommonly in later life develop gallstones, and there is a tendency in migraine for the blood cholesterol to be slightly above normal. The onset of migraine may coincide with the development of a duodenal ulcer. Biliary drainage by concentrated magnesium sulphate solution is sometimes of value in treatment.

Psychological Factors

Sufferers from migraine, though often mentally well balanced, and among the most intelligent and industrious members of the community, are not uncommonly of an introverted or obsessional temperament, and attacks of migraine may be precipitated by mental fatigue or anxiety.

Endocrine Factors.

On the whole there is little evidence that endocrine abnormality is important. The occurrence of 'menstrual migraine' has been quoted in favour of an ovarian disturbance. The pituitary has also been blamed, but the theory that a bridged sella turcica is a cause of menstrual migraine has not been generally accepted. Sufferers from exophthalmic goitre appear to be especially liable to migraine.

Heredity.

Hereditary predisposition is all-important. Migraine is often an hereditary disorder and is inherited as a Mendelian dominant. Here again appears a link with allergy, since asthma, hay fever, and other

allergic disorders are not uncommon among the relatives of the migrainous.

Association with Epilepsy.

Much stress has been laid by some writers on the alleged association of migraine with epilepsy. Both are common disorders and it is doubtful if their association in the same individual or in the same family occurs more frequently than can be explained by chance. Occasionally, however, a severe attack of migraine may terminate in an epileptic fit.

Age and Sex.

The age of onset is usually at or shortly after puberty, much less frequently in middle life or later, though an onset at about the menopause is not very uncommon in women. Migraine is rare before puberty, but cyclical vomiting is not uncommon in childhood in those who subsequently develop migraine. Women are slightly more subject to migraine than men and usually suffer more severely.

Symptoms.

The Onset.

Prodromal symptoms may be present or absent. The commonest of these are drowsiness and lassitude, hunger, and constipation or slight looseness of the stools. Sometimes the subject feels exceptionally well before an attack. The onset may occur during the day, which is usually the case in migraine with sensory symptoms. When headache is not preceded by these, the patient often awakens with it in the morning from a particularly heavy sleep.

Symptoms of Cortical Origin.

Sensory symptoms, though not constant, are highly characteristic. Visual disturbances are the commonest. These usually have a homonymous distribution, involving the corresponding halves of both visual fields. They usually consist of a gradually developing hemianopia, which may be preceded by positive symptoms such as flashes of light. The hemianopia may begin in the periphery of the field and spread towards the centre, or vice versa. A common mode of onset is the appearance of a bright spot near the centre. This gradually expands towards the periphery, the advancing edge exhibiting scintillating figures which may be coloured and angular—*teichopsia*, or *fortification spectra*. The spreading scintillation leaves behind it an area of blindness, so that when it reaches the periphery of the half-fields the patient is left with homonymous hemianopia. The spread of these visual symptoms occupies from fifteen to twenty minutes,

and the hemianopia then gradually fades away in the order of its
development, the whole disturbance lasting about half an hour,
though objects in the affected fields may appear less bright than
normally for several hours. Many varieties of migrainous visual
disturbance occur. The symptoms may have a homonymous quad-
rantic distribution. Very rarely peripheral vision is lost in the whole
of both fields, leaving only a 'telescopic' central field of vision.
Exceptionally also the hemianopia is bilateral and leads to temporary
complete blindness.

Paraesthesiae and numbness of parts of the body occur next in
frequency to visual disturbances. These symptoms possess a cortical
distribution, involving the periphery of the limbs and the circumoral
region. The upper limb is most often affected, a tingling sensation
beginning in the periphery and gradually spreading up the limb,
taking fifteen or twenty minutes to do so. The lips, face, and tongue
may be subsequently affected on one or both sides, or may be in-
volved without the upper limb. The lower limb is rarely the site of
paraesthesiae. Paraesthesiae usually develop shortly after the onset
of the visual disturbances, but may occur without the latter as the
first symptom. Less frequently they do not develop until after the
headache has been present for several hours.

Gustatory and auditory hallucinations have occasionally been
reported, but are rare.

Weakness of a limb, usually the upper, or of half of the body may
occur and usually follows the paraesthesiae.

Aphasia, usually of the expressive, less often of the receptive,
type, may occur. In right-handed people it may be associated with
visual disturbances in the right half-fields and paraesthesiae on the
right side of the body.

Transitory diplopia may be complained of during an attack.
Giddiness is not uncommon and there is often slight mental con-
fusion.

Headache.

Headache is the most characteristic symptom of migraine and the
one from which it derives its name. It may be the only manifestation
of the disorder or may follow the sensory symptoms just described.
It usually occurs as a boring pain in a localized area on one side,
often in the temple, and gradually spreads till the whole of the
affected side of the head is involved. Headache occurs on the side
opposite to that to which the sensory symptoms are referred. Some-
times it extends to the whole head. It gradually increases in intensity
and acquires a throbbing character, being intensified by stooping
and by all forms of exertion. In milder cases it lasts for several hours

but passes away if the patient can sleep, or after a night's rest. In more severe cases it persists for days.

Nausea is usually present during the stage of headache, and vomiting may or may not occur. In milder cases it seems to relieve the headache.

Vasomotor changes are often conspicuous. The face is often pale and the extremities are cold, until improvement begins, but congestion of the face, conjunctiva, and nasal mucous membrane may occur, and is often confined to the side of the headache. There may be subconjunctival haemorrhage. The superficial temporal artery on the affected side is congested and exhibits vigorous pulsation.

There is often polyuria following the attack.

Varieties of Migraine.

The commonest form of migraine is characterized by headache alone, or by headache and vomiting without other symptoms. Somewhat less frequently visual or sensory disturbances precede the headache. Less often still the visual or sensory symptoms, motor weakness, or aphasia are not followed by headache. Exceptionally vomiting may occur alone or in association with abdominal pain.

Migrainous Neuralgia.

The term migrainous neuralgia is applied to neuralgic pain, associated with tenderness, in the superficial tissues of the scalp or face, especially the temple, which may persist for days after an attack of migraine or may occur independently of migraine in a migrainous subject.

Ophthalmoplegic Migraine.

This term has been applied to recurrent attacks of headache associated with paralysis of one or more oculomotor nerves, which persists for days or weeks after the attack and tends to become permanent. Although transitory diplopia is occasionally associated with true migraine the diagnosis of migraine should be received with great suspicion when it is used to cover ocular palsies lasting more than an hour or two. It is probable that most cases hitherto described as ophthalmoplegic migraine have been examples of intracranial aneurysm, intracranial neoplasm, or some other slowly progressive organic lesion.

Facioplegic Migraine.

Recurrent facial palsy associated with migraine is very rare: I have seen one example. It is probably to be explained in the same way as ophthalmoplegic migraine.

Retinal Migraine

Retinal vascular lesions in migraine are fortunately rare. I have seen thrombosis of the central artery of the retina, and of single branches, and known recurrent attacks of retinal ischaemia lead to bilateral optic atrophy with an irregular peripheral constriction of the visual fields. Retinal and vitreous haemorrhages may also occur

Course and Prognosis.

The frequency of attacks of migraine varies considerably in different patients. Often the disorder seems to possess a rhythm which is little influenced by outside factors. The attacks may occur once a week, once a fortnight, or once a month, with great regularity Attacks in which headache occurs alone are usually more frequent than those in which it is preceded by sensory symptoms. The latter usually recur at intervals of several months. Occasionally a patient has repeated frequent attacks, a condition which may be called status hemicranialis by analogy with status epilepticus. Headache preceded by visual symptoms may occur more than once a day for a period of days. Apart from treatment, attacks tend to grow less frequent and less severe as the patient grows older and usually cease in late middle life. It is not uncommon for the character of the attack to change. For example, visual symptoms may cease to appear.

Migraine does not shorten life, but in severe cases in women a state of chronic exhaustion may occur. In a small number of cases permanent hemianopia or other visual field defects have followed an exceptionally severe attack. In such cases teichopsia may persist for weeks. Very rarely permanent aphasia and hemiplegia have occurred but this should suggest intracranial angioma rather than migraine.

Diagnosis.

It is important to distinguish migraine from similar symptoms resulting from organic disease of the brain. The early onset of migraine is an important point of distinction, since migraine usually begins at puberty whereas most organic conditions with which it may be confused are encountered in adult life. A tumour of the occipital lobe, especially an angioma, may lead to attacks of visual hallucinations associated with headache and vomiting. In these cases, however, careful perimetry usually shows a visual field defect which persists between the attacks and increases. Moreover, signs of increased intracranial pressure sooner or later develop, and there may be evidence of pressure exerted by the tumour upon the neighbouring parts of the brain and in a case of angioma a cranial bruit.

Also I have seen migraine simulated by an aneurysm of the internal carotid artery compressing the optic nerve. In this case attacks of dimness of vision, preceded by subjective flashes of light, occurred in the affected eye, together with headache. Papilloedema, a persistent field defect, and reduction of visual acuity, were present in this eye, together with other focal symptoms of the aneurysm.

Migraine is occasionally confused with epilepsy, since visual hallucinations may constitute the prodromal symptoms of both. In migraine, however, the progress of the attack is slow, in epilepsy it is rapid; and the retention of consciousness in the former should put the diagnosis beyond doubt.

When transitory attacks of paraesthesiae, weakness, and aphasia occur in migraine without headache, the diagnosis may be difficult. Such disturbances may simulate disseminated sclerosis or cerebral vascular lesions. In migraine, however, there is usually a history of previous attacks of headache, dating from an early age. The transitory apoplectiform episodes of cerebral arteriosclerosis are confined to late middle age and old age, and attacks of paresis or paraesthesiae in disseminated sclerosis, which usually last for several days, thus differ from those of migraine, which usually last only half an hour or at the most a few hours. When headache occurs alone, it must be distinguished from pain in the head due to other causes: see pp. 276-9.

Treatment.

The sufferer from migraine should endeavour to regulate his life so as to avoid as far as possible fatigue, both mental and physical. Refractive errors, if present, should be corrected. Diet is important, but individual idiosyncrasies are marked. Most patients benefit from a diet in which animal fats are restricted; and other articles of diet likely to precipitate attacks include eggs, chocolate, potatoes, and raw fruit, especially apples and oranges. When protein sensitivity is shown to exist specific desensitization may be tried, or non-specific desensitization by means of subcutaneous injections of peptone. Meals should be taken regularly and glucose may with advantage be added to the diet. In contrast there are some patients who improve on a ketogenic diet.

When there is reason to suspect defective hepatic function, cholagogues may be given, for example two tablets of Decholin (Riedel) thrice daily. Magnesium sulphate may be given in doses of 2 to 4 drachms of a 50 per cent. solution before breakfast once a week; and good results have been reported after periodical duodenal lavage followed by the instillation into the duodenum of 1 ounce of 33½ per cent. solution of magnesium sulphate.

When the attacks occur at the menstrual periods benefit may follow the subcutaneous injection of ovarian follicular hormone three times during the preceding week. Alternatively placental hormone—Emmenin complex (Glaxo)—may be given in doses of ½ to 1 drachm daily, except during the menstrual period.

Phenobarbital is a most useful drug for the prevention of attacks It should be given in doses of half a grain three times a day for two months, then twice a day for two months, and finally in a single dose *at bedtime for two months. Ergotamine tartrate has a highly* specific effect on the headache. Two mg is given at the onset and repeated in an hour if necessary. It is more effective dissolved under the tongue than swallowed. The subcutaneous dose is ½ mg. A prophylactic dose of 1 mg. may be taken nightly over a long period There seems no risk of ergotism but pregnancy and arteriosclerosis are contra-indications and rarely a single dose may cause thrombophlebitis. The bromides are also of value, but are less effective than phenobarbital. Nitro-glycerine is also useful, and a mixture recommended by Gowers includes:

℞							
Sod. brom.	.	.	.	.	.	.	gr. 10
Liquor trinitrin	.	.	.	.	.	ℳ. ½ to 1
Tinct. nuc. vom.	.	.	.	.	.	ℳ. 5
Tinct. gelsemii .	.	.	.	.	.	ℳ. 10
Acid. nitric. or hydrobrom. dil. .		.	.	.	ℳ. 5
Aq. chloroformi	.	.	.	.	ad ½ oz. t.d.s.

At the onset of an attack an attempt may be made to abort it by means of a dose of 30 grains of potassium bromide, with aspirin, 10 gr., and phenacetin or pyramidon, 10 gr.

During the attack the patient should lie down in a darkened room. A powder containing aspirin, gr. 10, phenacetin or pyramidon, gr. 10, caffeine citrate, gr. 3, should be given and can be repeated in two hours, if necessary. Some patients benefit from the addition of small doses of calomel. Counter-irritants, such as menthol, methyl salicylate, or capsicum, may be applied to the scalp. If vomiting is severe, small quantities of iced fluids should be given.

Very severe attacks of migraine, in which headache and vomiting persist for days, may yield only to morphine, though this drug should be avoided if possible on account of the risk of habituation.

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2. EPILEPSY

Definition.

Epilepsy is a paroxysmal and transitory disturbance of the functions of the brain which develops suddenly, ceases spontaneously, and exhibits a conspicuous tendency to recur. Though in its most typical forms it is characterized by the sudden onset of loss of consciousness, *which may or may not be associated with tonic spasm* and clonic contractions of the muscles, many varieties of epileptic attack occur, and it is probable that their distinctive features depend upon differences in the site of origin, extent of spread, and nature of the disturbance of function.

The Physiological Nature of Epilepsy.

The invention of electro-encephalography (see p. 132), though it has posed many problems which are still unsolved, has thrown much new light upon the nature of epilepsy. The electro-encephalograms obtained in epilepsy are described in more detail later. For our present purpose it is sufficient to say that epileptic attacks involving the cortex are accompanied by distinct and characteristic fluctuations in the changes in electrical potential of the brain. Characteristic rhythmical patterns have been found to correspond to different clinical types of attack and abnormal foci of electrical discharge have been found in many cases to persist between the attacks. These observations have led some workers to take the view that epilepsy is due to the development of abnormal rhythms in the cerebral cortex, and it has been described as a 'paroxysmal cerebral dysrhythmia' (Gibbs, Gibbs, and Lennox, 1937). The nature of such a dysrhythmia has still to be interpreted in terms of the functions of

the cortical neurones, but in spite of its many unsolved problems this recent work supports the view that the physiological basis of a convulsion is a discharge of cortical neurones rather than primarily impairment or loss of cortical function. Experimentally it can be shown in animals that convulsant drugs induce fits, the pattern of which can be modified by the successful removal of different levels of the nervous system *from the cortex downwards* Moreover, electrical stimulation of the cortex in man, as shown especially by Foerster, results in convulsions which can only be satisfactorily interpreted as the expression of a regional cortical discharge It is not difficult to explain loss of consciousness on the excitatory hypothesis, for consciousness must surely depend in large measure upon the blockage by inhibition of nerve-paths not immediately concerned A widespread cortical discharge would thus be as fatal to consciousness as cortical paralysis. Though cortical neural discharge plays the leading part in most convulsions, discharges probably also occur simultaneously in lower centres, and exceptionally these may take the lead in moulding the pattern of the fit.

Epilepsy, then, is to be regarded as an uncontrolled neural discharge, that is, as an abnormal conversion of the potential energy of the neurones into kinetic energy. Fundamentally, therefore, it is a physico-chemical disturbance, and it is to be expected that the causative abnormal physico-chemical state of the neurones should be produced by a wide variety of agencies.

Aetiology.

The following classification of the principal causes of epilepsy is for convenience arranged schematically, but it must be remembered that the precise way in which a cause operates is often obscure and in some instances a single pathological condition might be placed in more than one category.

(a) *Local Causes*

    (i) *Increased intracranial pressure:*

        Intracranial tumour, hypertensive hydrocephalus, subarachnoid haemorrhage.

    (ii) *Inflammatory conditions:*

        Meningitis; all forms of acute encephalitis; neurosyphilis; disseminated sclerosis; cerebral cysticercosis.

    (iii) *Trauma:*

        Intracranial haemorrhage of the newborn: head injuries of later life.

    (iv) *Congenital abnormalities.*

        Congenital diplegia; tuberous sclerosis; porencephaly.

(v) Degenerations:
    Cerebro-macular degeneration; diffuse sclerosis; Pick's disease; Alzheimer's disease.

(vi) Circulatory disturbances:
    Cerebral atheroma, haemorrhage, thrombosis, embolism; eclampsia; hypertensive encephalopathy; heart-block (Stokes-Adams Syndrome); stimulation of the carotid sinus; Raynaud's disease.

(b) General Causes.

(i) Exogenous poisons:
    Alcohol, absinthe; thujone; cocaine; lead; chloroform; ether; camphor; cardiazol; arseno-benzene.

(ii) Anoxaemia:
    Asphyxia; carbon monoxide poisoning; nitrous oxide anaesthesia; profound anaemia.

(iii) Disordered metabolism:
    Uraemia; acute yellow atrophy of the liver; hypoglycaemia; alkalosis; water retention.

(iv) Endocrine disorders:
    Parathyroid tetany; menstruation; pregnancy; ? hypopituitarism.

(v) Allergy:
    Epilepsy associated with asthma or other allergic states.

(vi) Conditions associated with childhood:
    Teething; rickets; acute infections.

(c) Psychological Factors.

These are relatively unimportant. It is doubtful if psychological factors alone are sufficient to cause epileptiform convulsions. In individuals otherwise predisposed, however, fright or anxiety may precipitate attacks.

(d) Idiopathic Epilepsy.

When all the above factors have been excluded there remains a large group of patients who suffer from convulsions for which no local or general cause can be found. We seem, therefore, compelled to regard these individuals as suffering from a predisposition to convulsions, the nature of which is not yet understood, but it must be borne in mind that the distinction between 'idiopathic' and 'symptomatic' epilepsy is not clear-cut. There is an intermediate group of patients in whom predisposition determines the development of epilepsy after a focal cerebral lesion such as a head injury.

The History of Patients Suffering from Epilepsy.

The following inquiries should be made of a patient suffering from convulsions.

When did the first fit occur ? Was it precipitated by an accident or associated with an acute illness ? How soon was it followed by the second ? What is the usual interval between the attacks ? Are they increasing in frequency ? Do the attacks occur in bouts ? Has the patient had a series of attacks without recovering consciousness ? Do the attacks occur at any special time of the day ? Do they occur only by day or only by night ? In the case of a woman, are they related to the menstrual periods ? Is any factor known to precipitate the attacks ? Does the patient have any warning ? If so, what, and how long does it precede the attack ? How does an attack begin ? Is its onset local or general, gradual or sudden ? Is consciousness lost ? Do convulsive movements occur in the attack ? If so, are they symmetrical or asymmetrical ? Has the patient injured himself in an attack ? Does he bite his tongue and pass urine ? How long do the attacks last ? What is his condition afterwards ? Are the attacks followed by headache, sleepiness, paralysis, or mental disturbance, such as automatism ? What treatment has he had and how has he responded to it ? Has he at any time suffered from head injury ? If the attacks did not begin in infancy, did he suffer from infantile convulsions ? Is there a family history of epilepsy or of fainting fits ?

IDIOPATHIC EPILEPSY

Aetiology.

The Nature of the Epileptic Convulsions.

As we have seen in the previous section, a convulsion must be regarded as an *uncontrolled nervous discharge*. When all recognized local and general causes of convulsions have been excluded there remains the group of patients suffering from idiopathic epilepsy. The precise mechanism which brings about the attack in epilepsy is obscure. It has long been held that the underlying disturbance was a sudden constriction of the arterioles or capillaries of the brain, but this is unsupported by careful studies of the intracranial blood-flow, and is inconsistent with electro-encephalographic observations of persistent abnormal cortical rhythms. The cause of the 'dysrhythmia' is still unknown.

Heredity.

Inherited predisposition plays a considerable part in the aetiology of epilepsy. In a series of 200 epileptics there was a family history of the disease in 28 per cent. This figure probably underestimates

the proportion suffering from an inherited tendency, since this does not always find expression, and minor manifestations of epilepsy are often unrecognized. It was found that the onset of the convulsions appeared earlier in patients with a family history of the disease than in those without this. It is difficult to estimate the liability of an epileptic parent to transmit the disorder to his or her offspring, since inheritance is often indirect and the condition reappears in a collateral line. Probably not more than 10 per cent. of the children of epileptics develop epilepsy.

Trauma.

The role of trauma in causing epilepsy is difficult to estimate. It is well known that severe head injuries may be followed by epilepsy, yet this sequel only occurred in a small proportion of cases, 4·5 per cent. of gun-shot wounds of the head during the 1914 war (see also p. 337). There is evidence also that lesions of the nervous system *predispose* to epileptic attacks, *for example* infantile hemiplegia. That minor cerebral lesions are also of some aetiological importance is indicated by the frequency with which slight abnormalities are found in the nervous system in epileptics. For example, Hodskins and Yakovlev in three hundred epileptics in an institution found a completely normal nervous system in only 17 per cent.

Epilepsy is relatively commoner among firstborn children than among later members of the family, and this is probably explained by the increased liability of the firstborn to head injury during birth.

Metabolic and Endocrine Factors.

Prolonged search has not revealed any constant metabolic abnormality in epileptic patients, though hints are not wanting that some *metabolic disturbance may play a part in the production of the fits.* Generalized convulsions may occur in tetany due either to alkalosis or to destruction of the parathyroids, and in epileptics, as Rosett has shown, a fit can often be precipitated if alkalosis is induced by over-breathing. There is no evidence, however, that normally alkalosis is responsible for the attacks. Attacks may be induced in some epileptics by water retention. A small proportion of patients are of the obese type associated with hypopituitarism. Adolescent epileptics are often tall for their age and present an appearance suggestive of functional overactivity of the anterior lobe of the pituitary. Abnormalities in the distribution of pubic hair are not uncommon. In fact many epileptics fall into the group which Kretschmer describes as dysplastic. The role of menstruation in precipitating the attacks in women is unexplained, but *supports the view which* attributes importance to metabolic factors. Pregnancy may also

influence the attacks. It is not uncommon for an epileptic woman to be free from attacks during *pregnancy* or even to be free when she is pregnant with children of one sex and not with the other. Others, again, are worse when pregnant. The truth probably is that epileptics are usually made worse by any change in their internal environment.

Allergy.

Allergy may be a causal factor in a few cases, especially in patients who also suffer from asthma or other allergic states.

Psychological Factors.

There is little reason to believe that epileptic attacks, as distinct from hysterical fits, are ever purely psychogenic, though the first fit is often ascribed to a fright. It is not uncommon, however, to find that the sufferer from epilepsy may develop a fit under the influence of fear or excitement

Sex and Age.

Females suffer from epilepsy slightly more frequently than males In Gowers's series of 3,000 cases the ratio of females to males was 13 : 12. In three-quarters of all cases the disorder first manifests itself under the age of 20, almost half the cases beginning during the second decade of life. Only 10 per cent. develop after the age of 30 (Gowers). During the first twenty years of life the onset of convulsions occurs more frequently at certain ages than at others The liability is high during the first three years; there is a peak at 7, corresponding to the second dentition; and a further peak at 14, 15, and 16. Apart from cases in which the attacks begin during infancy and continue without remission, epileptics have a special liability to infantile convulsions with a subsequent period of freedom from fits, which may last for years Patrick and Levy consider that infantile convulsions occur in about 40 per cent of epileptics, as compared with 4 per cent. of normal children.

Pathology.

There is no constant pathological change to be found in the brains of epileptics, though abnormalities are common. Bateman (1936) studied 178 brains of persons who had had convulsions. Only 2 were normal. In 34 there were acquired pathological lesions such as encephalitis and meningitis. In the remaining 142 cases the clinical condition was idiopathic epilepsy associated with some degree of amentia or dementia. In 60 out of 66 in whom the convulsions began before puberty there was bilateral agenesis of the frontal lobes. In

68 cases in which convulsions began after puberty frontal agenesis
was absent but there were focal vascular, meningeal, or ventricular
abnormalities. Microscopically much attention has been directed to
focal lesions in Ammon's horn. When recent these consist of foci
of tissue destruction which are later followed by gliosis. Spielmeyer
considers that these changes are the results of vascular spasm.

Symptoms.

Major Epilepsy (Grand Mal).

Pre-convulsive Symptoms. Epileptic patients frequently exhibit
symptoms which precede an attack for hours, or even for a day or
two, and which enable those about them to recognize that a fit is
likely to occur. These pre-convulsive symptoms include mental
changes such as irritability and depression, abnormal feelings referred
to the head, giddiness, and sudden myoclonic twitches.

The Aura. The aura, or warning of the attack, occurs according
to Gowers in three-fifths of all cases. It is a symptom produced by
the beginning of the epileptic discharge and perceived by the patient
before consciousness is lost. In the remaining cases the patient
experiences no warning, but becomes unconscious at the onset of
the fit. Since the focus of origin of the fit may be situated in a variety
of localities within the brain there is a corresponding variety of auras.
The aura may take the form of a complex mental state, such as a
feeling of unreality or on the other hand of familiarity, as though
events being experienced have happened before. The patient may
feel that he is disembodied, or he may experience an intense but inex-
plicable fear. *This last aura is sometimes associated with running,*
the patient running several yards before falling unconscious—'cursive
epilepsy'. The aura may be referred to one of the special senses:
olfactory and gustatory hallucinations may occur; visual auras may
consist of complex scenes or simple flashes of light or balls of fire;
auditory auras may take the form of hallucinations of hearing words
or phrases uttered, or may consist merely of crude sounds. Vertigo
is a common aura, and Foerster has shown that a convulsion begin-
ning with an aura of vertigo can be excited by electrical stimulation
of the interparietal sulcus. Sensory auras may consist of sensations
of numbness, tingling or electric shocks referred to part of the body,
or there may be a sensation as though a limb were shrivelling up.
Painful sensory auras occur, but are rare. Abnormal visceral sensa-
tions frequently constitute the aura, the patient experiencing a
peculiar sensation or sometimes even pain in the epigastrium. There
are many forms of motor aura. There may be a strong impulse to
speak associated with a feeling of inability to do so. The fit may
begin with spasm or clonic movement of part of the body, for

example, turning of the head to one side or flexion of the upper limb and the patient may be aware of the movement before he loses *consciousness. Sometimes the whole body is rotated to one side*

The Convulsion.

The convulsion may begin with the epileptic cry, a harsh scream due to forcible expiration of air through the partly closed vocal cords, *but this is more often absent than present Consciousness is* lost either immediately after the aura or at the very beginning of the attack, and the patient falls to the ground He usually has no recollection of falling. In the fall he may injure himself and permanent scars on the face from this cause are common in epileptics *The first motor manifestation of the convulsion proper is usually a* phase of tonic spasm of the muscles. This is for the most part symmetrical on the two sides of the body, though it is common for the head and eyes to be rotated to one side and for the mouth to be drawn to one side by asymmetry in the degree of facial spasm *The upper limbs are usually adducted at the shoulders and flexed at the elbows* and wrists. The fingers are flexed at the metacarpo-phalangeal and extended at the interphalangeal joints, the thumb being adducted The lower limbs are usually extended, with the feet inverted The respiratory and trunk muscles partake in the spasm and respiration *is arrested. The tonic phase may last only a few seconds and rarely* endures more than half a minute.

It is followed by the clonic phase, in which sustained tonic contraction of the muscles gives place to sharp, short, interrupted jerks As Gowers pointed out, the clonic phase is probably a series of interruptions of the tonic contraction, rather than an essentially different phenomenon, and Cobb has shown electro-myographically that both are tetanic.

In the clonic phase the tongue may be bitten if it is caught between the teeth when the jaw is closed. Foaming at the mouth may occur, and the saliva may be blood-stained if the tongue has been bitten. Incontinence of urine often occurs. Incontinence of faeces is less common.

At the onset of an epileptic fit the patient may be either pale or flushed. He becomes progressively cyanosed during the arrest of respiratory movements which occurs in the tonic stage, the cyanosis passing off when respiration is re-established in the clonic stage. Subconjunctival haemorrhages may occur. There is often profuse sweating. The pupils become dilated at the beginning of the fit and the reaction to light is usually lost The corneal reflexes are also lost in a severe fit; the tendon reflexes may be abolished and the plantar reflexes may be extensor for a short time after the attack.

The Post-convulsive Phase.

Towards the end of the clonic phase the intervals between the muscular contractions become longer and the jerks finally cease. The patient remains unconscious for a variable time, usually from a few minutes to half an hour and on recovering consciousness often sleeps for several hours. Headache is common after an attack. Usually after recovering consciousness the patient is mentally normal. Exceptionally, however, a convulsion is followed by an abnormal mental state. In post-epileptic automatism the patient, though apparently conscious, may carry out a series of actions which are often inappropriate to the circumstances and of which he subsequently has no recollection. Sometimes the epileptic fit passes into an hysterical attack. Rarely the epileptic patient may become maniacal after a convulsion and in this state may commit a crime of violence, even murder. Post-epileptic mental aberration follows petit mal more frequently than major epilepsy.

Minor Epilepsy (Petit Mal).

Minor epilepsy is a term applied to slight epileptic attacks in which impairment or loss of consciousness is the most prominent symptom. No hard and fast line, however, separates minor from major attacks.

The slightest form of petit mal, often described by the patient as a 'sensation', consists of a disturbance of consciousness often similar to the aura of a major attack, and sometimes associated with giddiness. In a 'sensation' consciousness may not be completely lost. Next in severity comes complete loss of consciousness, preceded or not by an aura, but the motor and postural functions of the brain are so little affected that the patient remains standing and does not fall. He looks somewhat dazed, and the eyes have a staring appearance. After a few seconds he recovers and may continue what he was doing before the attack. In more severe forms of petit mal the motor and postural functions are affected, and the patient, besides losing consciousness, may fall to the ground or may exhibit slight muscular rigidity, or carry out a brief stereotyped movement. Transitory pallor usually accompanies an attack of petit mal. Incontinence of urine may occur, though it is less frequent than in major attacks.

Psychomotor Attacks.

In these attacks the patient, though not unconscious, becomes confused, often anxious and negativistic, and carries out movements of a highly organized but semi-automatic character. The attack lasts from a few seconds to a minute or two.

Other Forms of Epileptic Attacks.

Jacksonian Epilepsy. Jacksonian epilepsy is fully described elsewhere. A convulsion with a focal onset and a gradual spread corresponding to the representation of parts of the body in the precentral convolution is almost always a symptom of organic disease of the brain in this region. A similar focal onset is not uncommon in idiopathic epilepsy, but in such cases the spread of the convulsion is more rapid than in a typical Jacksonian attack and consciousness is lost early.

Epilepsia Partialis Continua. This is a rare form of focal convulsion in which occur persistent clonic movements, which are confined to a limited part of the body, and which may continue for months without stopping.

Inhibitory Epilepsy. This is a very rare form of attack in which transitory loss of power occurs in a limb or in one-half of the body without precedent tonic spasm or clonic movements. It may or may not be associated with impairment or loss of consciousness.

'Tonic Epilepsy'. A convulsion may consist of an attack of muscular rigidity associated with loss of consciousness but not followed by clonic movements. In the usual form of tonic convulsion the posture of the body differs from that of the tonic phase of a major epileptic attack. The head is extended, the upper limbs are thrown out in front of the patient, extended at the elbows, internally rotated and hyperpronated, with the fingers somewhat flexed. The lower limbs are extended. This type of fit is usually the result of organic disease of the brain (see p. 11), *but occurs occasionally in idiopathic* epilepsy.

Sensory Epilepsy. These consist of paraesthesiae, such as tingling or 'electric shocks', less frequently of painful sensation, involving usually a part or the whole of one side of the body. They may occur without loss of consciousness and are usually the result of a lesion in the opposite parietal lobe.

Uncinate Epilepsy. This term has been applied to attacks characterized by hallucinations of smell or taste. They are often *accompanied by movements of the lips, tongue, and jaw*, for example, those of tasting or chewing, and are often associated with a disturbance of memory (see p. 895). Uncinate fits are *usually the result* of organic disease in the region of the uncinate gyrus (see p. 248). They may, however, occur as a manifestation of idiopathic epilepsy.

Reflex Epilepsy. It occasionally happens that a convulsion may be excited by some form of external stimulation. This may be a sudden loud noise—acoustico-motor epilepsy—or music—musicogenic epilepsy—or a visual or cutaneous stimulus. Somewhat similar

are cases in which a voluntary movement may precipitate an attack.

Reflex inhibition of a fit is an allied phenomenon. When a convulsion has a focal onset and begins with movement, for example, of one limb, it is not uncommon to find that a strong stimulus, such as a firm grip, rubbing, or passive movement applied to the limb, will abort an attack, if it is begun immediately after the onset.

Pyknolepsy. Pyknolepsy is a term which has been applied to a form of epilepsy characterized by very frequent attacks of petit mal. It occurs in children, and the patient may have over a hundred minor epileptic attacks a day. The onset is usually sudden and the attacks may cease spontaneously. They respond very little to treatment.

Myoclonus Epilepsy. See p. 886.

The Time Relationship of Attacks.

Individuals differ greatly in respect of the frequency of their attacks. At one extreme are those who have only one, or perhaps two, in a lifetime; at the other, those who are convulsed several times a day.

As Gowers points out, there are three common modes of onset of the convulsions. A patient may have petit mal for a long period before beginning to have major fits. Alternatively the first attack may be a severe one and thereafter major fits may occur at short intervals, with or without attacks of petit mal in addition, or there may be major attacks separated by long intervals of months or even years. In 76 per cent. of Gowers's cases the intervals between attacks were less than one month. Some patients always have fits in groups of two or more within a few hours.

Time of day is an important factor in determining the occurrence of fits. In 42 per cent. of a series of cases attacks occurred by day only, in 24 per cent. by night only, and in the remainder both by day and by night. When the fits were confined to the day they occurred only half as frequently as in the other two groups. Nocturnal fits are most likely to occur shortly after going to sleep and between 4 and 5 a.m., while the commonest time for diurnal fits is during the first hour after awakening. Menstruation markedly influences the occurrence of fits in women. Many women have attacks only at the menstrual period, usually just before the period begins, less frequently during or immediately after. 'Long-distance rhythms' have been studied by Griffiths and Fox (1938).

Status Epilepticus. An epileptic patient may have a succession of convulsions with recovery of consciousness between the attacks—serial epilepsy. In some cases, however, one fit follows another without any intervening period of consciousness—status epilepticus.

Unless the convulsions can be arrested coma deepens and pyrexia, or even hyperpyrexia, develops and death occurs. Some patients exhibit a special tendency to develop status epilepticus and do so on many occasions.

Mental and Physical Abnormalities.

No mental or physical abnormalities are constantly associated with epilepsy and many epileptic patients exhibit neither. Epilepsy is sometimes associated with mental deficiency, and one easily recognizable type of mentally defective, epileptic child is excitable, noisy, destructive, and difficult to control The commonest mental abnormality in adult epileptics is a tendency to a certain morose egotism The cause of the progressive mental deterioration which sometimes accompanies epilepsy is obscure. It is probably not a direct result of the fits, since it may be absent in patients having frequent severe attacks. Possibly prolonged medication with bromide may be a contributory factor. It is probable that both the convulsions and the associated mild dementia are the expression of some unknown physiological abnormality.

In most cases examination of the nervous system reveals no abnormality in epileptics. Apart from gross lesions such as infantile hemiplegia and hydrocephalus, which predispose to epilepsy, it is not uncommon, however, to find slight abnormal physical signs, such as nystagmus, slight facial weakness, diminution of abdominal reflexes, and an extensor plantar response on one or both sides.

No constant endocrine abnormality has been found to be associated with epilepsy, though minor disorders of skeletal growth and genital development are common Many adolescent epileptics are exceptionally tall for their age Obesity of the hypopituitary and eunuchoid type is sometimes seen, together with a heterosexual distribution of pubic hair. Scattered spots of café-au-lait pigmentation of the skin are often present. Facial naevus should suggest an intracranial angioma on the same side, which may cause an audible bruit on auscultation of the skull In spite of numerous investigations no constant metabolic abnormality has been generally recognized.

The cerebro-spinal fluid is usually normal, though in 20 per cent. of cases its pressure is above 200 mm. of fluid In about the same proportion of cases the protein content of the fluid is above the upper limit of normal. Ventriculography and encephalography often show abnormalities such as dilatation of the ventricles or of the subarachnoid space overlying an area of the cerebral cortex, and such changes are most likely to be found when epilepsy has followed a head injury.

Electro-encephalography.

The electro-encephalogram (see p. 132) in epilepsy is highly characteristic. The phenomena of the attacks have been studied by Gibbs, Gibbs, and Lennox (1937). They find three main types of electro-encephalogram corresponding with the three main clinical types of seizure. In all types during the height of the seizure there is a great increase in voltage. In grand mal the waves increase in rate up to 25 to 30 a second and appear as sharp spikes. In petit mal quick, sharp spikes and slow round waves at the rate of 3 a second alternate. In psycho-motor attacks the rate slows to 3 or 4 a second with a square, flat-topped wave predominating. Some patients have subclinical seizures which are typical short discharges of rhythm not attended by subjective or objective evidence of an attack. Walter (1938) states that about 50 per cent. of epileptics under the age of 40 show some abnormality in the electro-encephalogram between the attacks. This consists of an abnormal focus of delta waves which in grand mal is most often in the region of the superior frontal gyrus on one or both sides. In petit mal the focus is usually post-central and in pyknolepsy it is in the occipital poles. When a fit begins the waves can be seen to start as an increase in the focal resting discharge, which spreads often quite suddenly to involve other parts of the cortex. Patients with traumatic epilepsy do not show a resting abnormal focus, though the seizure waves are the same as in idiopathic epilepsy. In epilepsia partialis continua a frontal electrical discharge corresponds in time and rhythm to the muscular contractions.

Diagnosis.

The diagnosis of epilepsy falls into two parts. It is first necessary to distinguish epileptic attacks from other paroxysmal disturbances, and secondly, to decide whether the attacks are symptomatic of organic disease or *metabolic disorder*, or *whether the patient is* suffering from idiopathic epilepsy.

Petit mal must be distinguished from *syncope*. Syncope usually occurs in weakly individuals with vasomotor instability or as the result of exhaustion or haemorrhage. Both the onset and the cessation of syncopal attacks are more gradual than is usually the case in petit mal, and the former is usually preceded by a feeling of faintness. In syncope also the patient is limp, whereas the occurrence of slight rigidity is in favour of petit mal.

Nevertheless, in some individuals pressure upon the carotid sinus or circumstances which usually induce syncope may cause an epileptic attack. For a discussion of the relationship between syncope and epilepsy, see p. 872.

In *narcolepsy* consciousness is lost, but convulsive movements are absent and the patient, unlike the epileptic, can be immediately roused. In *cataplexy* voluntary power is lost but consciousness is retained.

Aural vertigo may be confused with petit mal, in which also vertigo may occur. In vertigo of aural origin, however, consciousness is retained and other symptoms of aural disease, such as tinnitus and deafness, are usually present. Though an attack of aural vertigo may be brief it usually lasts longer than an attack of petit mal and passes away more gradually.

Hysterical convulsions are usually easily distinguished from epileptic attacks if the patient is seen when convulsed. Their onset is gradual, and they occur only in the presence of an audience. Consciousness is not completely lost, for the patient can usually be roused by forcible measures and an attempt to elicit the corneal reflex usually evokes a vigorous contraction of the orbicularis oculi. If the patient cries out during the attack he usually articulates words or phrases, and laughing and crying may occur. The movements which constitute an hysterical convulsion are not clonic jerks as in epilepsy, but such as can be carried out voluntarily, for example, clutching at objects in the neighbourhood. The tongue is not bitten, nor does incontinence of urine usually occur in an hysterical attack.

Anxiety attacks are occasionally confused with epilepsy. In these consciousness is not lost, but the predominant symptom is an intense sense of anxiety which is often associated with a feeling of giddiness, palpitation, and sweating.

Under the term *vaso-vagal attacks* Gowers described 'prolonged seizures, the symptoms of which consist chiefly in disturbance of some of the functions of the pneumo-gastric'. The patient complains of gastric, respiratory, or cardiac discomfort, and these symptoms are often associated with vasoconstriction and coldness of the extremities. Women are more subject to these paroxysms than men. They are distinguished from epilepsy by their gradual onset and longer duration, and by the usual absence of loss of consciousness.

Migraine is a paroxysmal disturbance which may simulate epilepsy. The onset of an attack of migraine, however, is gradual. Consciousness is not lost, and headache usually occurs. It must be remembered, however, that the same individual may suffer from both migraine and epilepsy and that very exceptionally a severe attack of migraine may terminate in an epileptic fit.

When it has been established that a patient suffers from epileptiform attacks, it remains to exclude the various focal and metabolic causes of convulsions enumerated on pp 853–4.

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Gross organic lesions such as *hydrocephalus* and *infantile hemiplegia* give rise to no difficulty.

Tuberous sclerosis can be diagnosed as a cause of epilepsy associated with mental defect only when adenoma sebaceum is present.

Renal disease and *hypertensive encephalopathy* may be excluded by examination of the cardio-vascular system, including the blood-pressure, and of the urine and the blood urea.

The diagnosis of *syphilis* can be established by means of the history, the presence of signs of the infection of the nervous system, and a positive Wassermann reaction in the blood or cerebro-spinal fluid.

When *alcohol* is the cause of the convulsions a history of alcoholism can usually be obtained.

Heart-block offers little difficulty in diagnosis if the possibility of its occurrence is borne in mind. The attacks are associated with marked bradycardia, and, even if the pulse-rate is normal between the attacks, impaired conduction in the auriculo-ventricular bundle can be demonstrated by an electrocardiogram.

Special consideration must be given to the two commonest causes of convulsions developing after the age of 30, namely, intracranial tumour and cerebral arteriosclerosis. In *intracranial tumour* convulsions may precede other symptoms by months or years, and when this is the case the true cause can only be suspected. Though convulsions due to cerebral tumour may be generalized, a focal origin for the attacks should suggest tumour, especially when they are followed by temporary aphasia or paresis. Sooner or later headache and other symptoms of increased intracranial pressure make their appearance, together with signs of a progressive cerebral lesion. Ventriculography may be helpful. Epileptiform attacks due to *cerebral arteriosclerosis* occur in late middle life and old age. Vascular thickening is usually demonstrable in the arteries of the retina and of the limbs, and the blood-pressure may be raised.

Cysticercosis should be considered especially when epilepsy begins in adult life in men who have lived abroad, especially in India, and search should be made for subcutaneous cysts. Calcified cysts may be demonstrated radiographically in the muscles and less often in the brain.

Prognosis.

The risks of death occurring during an epileptic fit are comparatively slight, except in status epilepticus, in which condition the *patient's life is always threatened until consciousness returns*, and death may occur even after recovery of consciousness.

When death occurs as the result of a fit it is not usually due to the fit itself but is an accidental result of the loss of consciousness. Thus a patient who is convulsed in bed may turn over and become as-

phyxiated through his face being buried in the pillow, and drowning may follow a convulsion which occurs when a patient is in a bath.

Minor accidents occurring from the fits include injuries induced by the fall, though these are rarely serious, and dislocation of the shoulder, which is produced by muscular action and which, having once occurred, is liable to recur in subsequent attacks. The prognosis *as to recovery from the attacks depends upon a number of factors.* To achieve recovery it is necessary to abolish the attacks by means of treatment for a sufficient length of time for the patient to *lose the epileptic habit. Persevering and thorough treatment is* therefore essential and must be continued for 2 or 3 years after the attacks have ceased. The sooner the treatment can be begun after the first fit, the better the outlook, and the prognosis is best in those in whom the attacks begin after the age of 20. A family history of the disease is not necessarily an adverse factor in prognosis, and patients with an epileptic heredity often do better than those without this Individuals suffering from frequent severe fits are least likely to be completely cured. According to Gowers the outlook is best when the attacks occur only during sleep, and treatment is most likely to be successful when they take place at a regular time of *the day or of the month, so that intensive treatment can be timed so* as to avert them. Marked mental deterioration makes the outlook worse. Thus few patients in institutions become free from attacks and the death-rate among institutional epileptics is four times that of the general population. Probably about 30 per cent. of non-institutional epileptics are cured in the sense of remaining free from attacks indefinitely.

Treatment.

General Management.

It is desirable that an epileptic patient should as far as possible live a normal life. Children should attend school and should be subjected to ordinary discipline. Adults should carry on an occupation, though certain trades will necessarily be ruled out Occupations involving working at heights, or near machinery, or driving vehicles are obviously unsuitable, and sufferers from epilepsy are now *precluded by law from obtaining a motor-driver's licence in Great* Britain. A regular occupation is a considerable prophylactic against fits. Certain risks of everyday life must be explained to the patient and his friends, but it is difficult, if not impossible, to guard him against them all. The water in his bath should be shallow and he should not *bathe in deep water unaccompanied. Institutional* treatment may be necessary for mentally defective patients and those having severe and frequent fits, if adequate home care is not

available. Those in whom the disorder renders an ordinary occupation impossible often do well at an epileptic colony.

No general rule can be laid down concerning the marriage of epileptics. There is no evidence that marriage affects the tendency to fits either beneficially or adversely, though pregnancy may prove either beneficial or the reverse. The risk of transmitting the disorder to the children must be individually assessed in each case. This risk is clearly greatest when there is a family history of epilepsy and least when a focal lesion of the brain can be held partly responsible for the attacks. Even when the epileptic tendency is hereditary it is exceptional for a patient to transmit the disorder in the direct line, and the chances are probably between 5 to 1 and 10 to 1 against any individual child of an epileptic parent developing epilepsy.

Careful attention must be paid to general hygiene in epilepsy. Moderate exercise is desirable, but violent exertion sometimes precipitates attacks. Any factor adversely affecting the general health especially enlarged tonsils, adenoids, and intestinal worms in children should receive attention. If there is evidence of an allergic reaction to certain foods these should be avoided, or desensitization may be tried. The diet, unless for special reasons it is to be restricted, should be ample and adequately supplied with vitamins, and care must be taken to ensure a daily evacuation of the bowels.

Treatment of the Epileptic Attack.

Treatment of a patient in an epileptic attack consists merely in preventing him from injuring himself. A gag should be placed between the teeth. The attack is self-limited, and no immediate treatment will shorten its course.

Surgical Treatment.

From the most ancient times trephining the skull has played a part in the treatment of epilepsy. Apart from intracranial tumours, however, this operation is probably of benefit only in a very narrowly restricted group of cases. When there is clear evidence of an organic lesion of the brain, especially one of traumatic origin, and the attacks have a focal onset which can be related to the lesion, and when ventriculography demonstrates displacement of the ventricular system towards the lesion or meningeal adhesions superficially to it, excision of scar-tissue from the affected area may abolish the attacks (Foerster and Penfield). Excision of the cervical sympathetic appears to be valueless.

Treatment with Drugs.

Certain drugs have been found to diminish the severity and frequency of epileptic attacks and in favourable cases to abolish

them completely. The object of drug treatment is to secure an abolition of the fits for a sufficient length of time to enable the patient to lose the epileptic habit. When the attacks occur regularly at the same hour of the day or period of the month, the doses are timed correspondingly so as to produce their maximal effect when the attack is expected. Thus when the attacks are nocturnal or occur in the early morning, a single dose at bedtime may be sufficient. When they occur only at the monthly periods, medication can sometimes be confined to the previous and subsequent weeks. When the fits are irregular a dose must be taken two or three times a day. Perseverance in treatment is essential and the patient must continue to take the effective drug 2 or 3 years after the attacks cease, if a relapse is to be avoided. Electro-encephalography may prove helpful in assessing the results of treatment which cannot safely be discontinued as long as abnormal cortical electrical rhythms persist.

Bromides.

For many years the bromides were the most effective drugs in the treatment of epilepsy. Combinations of bromine with various bases have been tried, but sodium and potassium bromide appear to be *the most effective, and there seems no advantage in using several* different bromides concurrently. It is still wise to begin treatment with bromide in most cases, since phenobarbital, though it may prove more effective, has certain disadvantages. The total daily dose of bromide should not exceed 60 grains, given in two or three doses. The action of bromide is facilitated if the patient's intake of chloride in the form of common salt is restricted. The most troublesome symptom of bromide ingestion is acne. This, however, can be largely, if not entirely, avoided, by giving 3 minims of liquor arsenicalis with each dose of bromide, though it must be remembered that the prolonged administration of arsenic may lead to cutaneous pigmentation or polyneuritis. Other symptoms of the prolonged administration of bromide are constipation, impotence, and an hallucinatory psychosis (see p. 675).

Barbiturates.

Phenobarbital (luminal or gardenal) is a derivative of barbital. It *is practically insoluble in water, but the sodium salt, phenobarbital sodium,* is readily soluble, though it is incompatible with ammonium salts and with acids. Phenobarbital possesses the advantages over bromide that it can be given in tablet form, that it often controls the attacks more effectively, and that it is less depressing. It possesses the disadvantage that if it is suddenly withdrawn, the patient may have more fits than before it was begun and may even pass into

status epilepticus. Patients with an idiosyncrasy for phenobarbital may develop an erythematous or an urticarial rash, while in toxic doses the drug may produce headache, *vertigo, lethargy, and impotence*, or even ataxia and mental confusion. Phenobarbital may be given either alone or in addition to bromide, beginning with half a grain night and morning and increasing up to 3 grains a day. If the drug is to be withdrawn, the doses of bromide must be increased and the patient should be warned against stopping the drug without advice. Phenobarbital is more effective in the treatment of major than of minor attacks.

Calcium-dibrom-ethyl barbituric acid (superminal) is sometimes more effective than phenobarbital. It may be given alone or with bromide, in doses of 0·5 gramme.

N-Methylethylphenylmalonylurea (prominal) is used in doses of from 3 to 15 grains a day, and the recently introduced sodium diphenyl-hydantoinate (epanutin) in doses of from 1½ to a maximum of 9 grains a day.

Other Drugs.

Other drugs are of value only as adjurants to bromide and phenobarbital, especially in cases which have not responded satisfactorily to these. Tincture of belladonna in doses of from 5 to 10 minims is sometimes useful, especially in the treatment of *petit mal*. Tincture of digitalis in 5-minim doses is also occasionally successful. Zinc salts have a long-standing reputation and may be tried in the form of 3- to 5-grain doses of the lactate. Sodium bi-borate in doses of 15 to 30 grains three times a day can be combined with bromide. Benzedrine in 5 mg. doses is sometimes useful in pyknolepsy. Endocrine preparations are of little value, though extract of corpus luteum is sometimes useful in women whose attacks occur at the menstrual periods, and small doses of thyroid extract should be given if the patient exhibits signs of retarded development.

Treatment of Status Epilepticus.

Phenobarbital has greatly simplified the treatment of status epilepticus, since the soluble sodium salt can be given subcutaneously or intravenously. The subcutaneous injection of 5 grains of luminal sodium is the surest method of cutting short an attack of status. This dose can be repeated if necessary.

An alternative mode of treatment is to administer *sedative drugs* by the rectum, and 60 grains of chloral or sulphonal, or 1 oz. of paraldehyde may be given in this way and repeated if necessary. If the convulsions continue *in spite of sedatives, light chloroform* anaesthesia should be used to control them.

The withdrawal of cerebro-spinal fluid by lumbar puncture is a useful adjuvant measure. Whether or not drugs are given by the rectum, the lower bowel should be well washed out with enemata, and rectal salines should be given if unconsciousness is prolonged

Dietetic Treatment

Geyelin, in 1921, observed that complete starvation caused a marked reduction in the number of fits in epileptics. Other workers acting on the hypothesis that the benefit derived from starvation was due to the associated ketosis, tried the effects of inducing ketosis by administering a diet rich in fats and poor in carbohydrates. A ketogenic diet has been found to be of some value in the treatment of epilepsy in children, but adults are less responsive. On such a diet about 30 per cent. of children become free from attacks, and in a further 20 per cent. the frequency of the attacks is reduced The diet is calculated in terms of the ratio of ketogenic (fat) to anti-ketogenic (protein and carbohydrate) substances in the foodstuffs This is described as the ketogenic: antiketogenic ratio It is usual to begin with a ratio of 2 : 1 increasing it as necessary up to 4 : 1, the urine being examined daily for acetone and diacetic acid, and the patient should be kept on a diet of a minimum ratio necessary to control the attacks Careful supervision is necessary, since the consumption of sugar, sweets, bread, or starchy food will lead to a relapse The patient should be weighed twice a week, since steady loss of weight would indicate the need for a revision, and possibly the abandonment of the diet. Vitamin deficiency should be guarded against by giving Marmite, cod-liver oil, and fresh tomato daily. If an ice-cream freezer can be obtained, cream and egg-yolks can be mixed, suitably flavoured and frozen, and thus rendered more palatable. Specimen ketogenic diets can be obtained from text-books of dietetics.

Water Restriction

Temple Fay has recently put forward a view that epilepsy is associated with a disturbance of water metabolism and that benefit results from drastic restriction of the patient's intake of water.

Psychotherapy

There is no reason to regard epilepsy as primarily a psychological disorder. In a few cases, however, mental stress and emotional difficulties appear to precipitate attacks. When such subordinate causes can be found, benefit may result from a course of psychological treatment.

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3. SYNCOPE AND SYNCOPAL EPILEPSY

Definition: Syncope is a brief and transitory loss of consciousness, occurring as a result of disorder of the circulation, and in the absence of organic disease of the brain. In most cases it is clear that the immediate cause is a reduction in the cerebral circulation, and if this is sufficiently prolonged, convulsions may occur. As will be seen there is evidence that in some cases syncope may occur in the absence of a change in the cerebral circulation, and also that in some individuals an isolated epileptic attack may be precipitated by circumstances which more usually cause syncope. The relationship between syncope and epilepsy is therefore to some extent obscure, yet it seems likely that what may be termed syncopal epilepsy is the outcome of a disorder of function different from that which underlies idiopathic epilepsy.

Aetiology.

There are many causes of syncope, and it will be convenient to consider first one which, though perhaps not the commonest, has been thoroughly investigated and throws much light on the symptom —*carotid sinus syncope*.

(1) *Carotid Sinus Syncope*.

The important part played in the regulation of the circulation by the carotid sinus, the slight dilatation of the carotid in the region of the bifurcation, was first pointed out by Hering, though previously

the vagus had been held responsible for effects now known to originate in the sinus. *A rise of pressure within the sinus causes a* reflex fall in blood-pressure with slowing of the heart-rate, while a fall of pressure within the sinus has the opposite effect. These reflex changes are mediated by the sinus nerve of Hering, a branch of the glosso-pharyngeal nerve, and the medullary vaso-motor centres. Disease in the neighbourhood of the sinus, or even hypersensitiveness of the reflex mechanism may cause syncopal attacks which can be reproduced by digital pressure in this region.

Ferris, Capps, and Weiss (1937) have described three types of carotid sinus syncope: (i) 'vagal' attacks in which unconsciousness is due to cerebral anoxaemia resulting from reflex cardiac asystole, (ii) attacks of a depressor type in which loss of consciousness is due to cerebral anoxaemia caused by a fall in blood-pressure, and (iii) a cerebral type of attack in which unconsciousness occurs without any significant change in heart-rate or blood-pressure and without change in the cerebral blood flow.

The causes of carotid sinus attacks include lesions in the neighbourhood of the sinus, such as scarring from tuberculous adenitis, atheroma of the artery, and rarely tumour. Among more general causes are the menopause and dietary deficiency associated with chronic alcoholism.

(2) Psychological Shock.

The occurrence of syncope as an immediate response to sudden psychological shock is well known, and is probably due to slowing of the heart and fall in blood-pressure

(3) Physical Shock.

A wide diversity of physical stimuli are capable of causing syncope. Severe pain, especially pain arising from injury to deep tissues or visceral disease, may cause loss of consciousness, but many stimuli which cause little or no pain may be equally effective, and any stimulus which may cause syncope in one person may cause an epileptic attack in another, who may show no other evidence of a predisposition to epilepsy. Such stimuli include venepuncture, cisternal and lumbar puncture, pleural puncture ('pleural epilepsy'), and severe coughing ('laryngeal epilepsy'). Severe vertigo may also cause syncope, for example in Ménière's syndrome.

(4) Drugs.

Exceptionally the administration of a drug to which the patient is hypersensitive causes syncope. Cocaine and the organic arsenicals sometimes act in this way.

(5) *Vaso-motor Instability.*

Vaso-motor instability is the explanation of syncope occurring in rapidly growing adolescents in hot rooms, and in those getting up after long confinement to bed. In the latter the normal reflex postural regulation of the blood-pressure requires to be re-established.

(6) *Anaemia of Sudden Onset.*

Anaemia of sudden onset due to severe haemorrhage may cause syncope, though an equally severe anaemia of more gradual onset does not

(7) *Disorders of the Cardiac Rhythm.*

Syncope may be caused by the impairment of the cerebral circulation resulting from disorder of the rate and rhythm of the heart in heart-block, auricular flutter, and paroxysmal tachycardia. Syncope and syncopal epilepsy in heart-block—Stokes-Adams's syndrome—is the best known of these disturbances. The loss of consciousness is most likely to occur during the cardiac asystole which may develop in the transition between partial heart-block and complete block, and the attacks may cease when the block is complete, but do not always do so. Many attacks may occur in a day

(8) *Hypoglycaemia.*

Syncope may be a symptom of hypoglycaemia due to an overdose of insulin in a diabetic patient, or of the chronic state of hypoglycaemia rarely produced by a tumour of the islet cells of the pancreas

(9) *Syncope of Central Origin.*

Rarely loss of consciousness may occur as a result of interference with the functions of the hypothalamus, particularly by a tumour (see diencephalic epilepsy, p 819 and vaso-vagal attacks, p. 876).

Symptoms.

The onset of an attack of syncope may be sudden, but it often takes a quarter to half a minute to develop. There may be prodromal symptoms such as coldness or tingling in the extremities, or loss of vision. The patient becomes pale and limp, and with the onset of loss of consciousness sinks to the ground, though the premonitory symptoms often enable him to sit or lie down first. Respiration is usually sighing, the pulse is generally slow, and the tension low. The pupils may be dilated and react sluggishly to light, and the corneal reflexes are likely to be lost and the tendon reflexes diminished. After a variable time, usually in from half a minute to two or three

minutes, consciousness gradually returns, the patient may vomit, and feels weak and dizzy.

Syncopal epilepsy may assume three forms. (1) *Symptoms usually associated with epilepsy may occur during an attack of syncope, e.g. slight twitching movements or loss of control over the bladder* (2) *If cardiac asystole is prolonged to several seconds the syncope merges into an epileptic attack, e.g. in heart-block* (3) *In response to a stimulus, such as usually causes a syncopal attack, a patient may suddenly and without warning have an epileptic attack*

Diagnosis.

Though as already described the relationship between syncope and epilepsy is close there is usually no difficulty in distinguishing between the typical syncopal attack and the typical attack of epilepsy. Syncope, being secondary to a circulatory change, is more gradual in both its onset and its cessation than an attack of petit mal Convulsive movements do not occur as a rule, and the patient is limp rather than rigid, as in epilepsy In many cases the cause of the syncopal attack is obvious. Syncope and epilepsy of carotid sinus origin can be reproduced by pressure on the sinus, which, however, is no longer effective after novocain has been injected into this region. In the stage of partial heart-block the diagnosis may be impossible without an electro-cardiogram: in complete block the heart-rate is usually from 26 to 30. Chronic hypoglycaemia may be suspected when recurrent syncopal attacks occur especially before meals, and can be confirmed by determining the blood-sugar level

Prognosis.

A syncopal attack in itself is rarely fatal and leaves no sequels. The prognosis is that of the causal condition The prognosis of syncopal epilepsy must be guarded, but the fact that a person has had an epileptic attack in response, for example, to a physical trauma does not by any means imply that further attacks of the same kind will occur.

Treatment.

Little treatment is required for the ordinary attack of syncope, which is self-limited. The patient should be placed in a horizontal posture. Smelling salts and brandy (if he can swallow) act reflexly as cardio-accelerators. Adrenaline or coramine can be injected but will hardly ever be required. Any causal condition will require treatment. Syncope of carotid sinus origin is best treated with small doses of bromide, combined with $7\frac{1}{2}$ to 10 minims of tincture of belladonna and $\frac{1}{4}$ to $\frac{1}{2}$ grain of ephedrine two or three times a day. In intractable cases it may be justifiable to denervate the sinus.

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disease. Its role in the causation of fainting and convulsions. *Medicine*,
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4. VASO-VAGAL ATTACKS

Definition: The terms 'vagal' and 'vaso-vagal' attacks were first
used by Gowers to describe 'prolonged seizures, the symptoms of
which consist chiefly in disturbance of some of the functions of the
pneumogastric'.

Aetiology.

Vaso-vagal attacks are uncommon and occur more frequently in
women than in men. They are most likely to take place in the early
morning, shortly after getting up, and are occasionally related to
menstruation, but as a rule no precipitating cause can be discovered.
Gowers was careful to state that he used the term 'vagal' for pur-
poses of description 'without implying causation'. Though the
attacks are characterized by symptoms which may reasonably be
attributed to a disturbance both of the sensory and of the motor
functions of the vagus, other symptoms may be regarded as in-
dicating overaction of the sympathetic. Vaso-vagal attacks therefore
appear to be paroxysmal disturbances of the functions of both con-
stituents of the autonomic nervous system, and recall the dience-
phalic autonomic epilepsy of Penfield. *Their cause is unknown.*

Symptoms.

The onset of symptoms usually occurs in early adult life. The
attack begins suddenly, usually with an abnormal sensation referred
to the epigastrium. This may be described as a sense of oppression
or a sinking feeling, or may be indescribable. It tends to spread to
the chest. Associated with the epigastric sensation there is often
a sense of dyspnoea combined with a sensation of disordered action
of the heart, such as slowing, irregularity, or increased rapidity of
the heart-beat. In some cases there is an intense feeling of impending
death—*angor animi*. During the attack the patient remains per-
fectly still, sitting or lying down. There is usually no impairment
of consciousness, though there may be difficulty in speaking. In
some cases the surroundings seem to the patient very distant, and
he is aware of what is happening as though it were in a dream.
Occasionally, as in one of Gowers's cases, consciousness is lost.

The pulse-rate is usually abnormally slow and may be irregular, and the volume of the radial pulse is often subnormal Generalized vasomotor spasm is a feature of the later stages of the attack, the extremities being cold and cyanosed and the patient experiencing a sense of chill. The face may be pale or flushed The duration of the attack varies in different cases from a few minutes to half an hour, and the patient afterwards usually feels weak and tremulous for several hours and may complain of headache

Diagnosis.

Since consciousness is usually retained, vaso-vagal attacks are readily distinguished from syncope and from epilepsy, in both of which it is lost. In the rare cases in which the patient loses consciousness the distinction of the vaso-vagal attack from epilepsy must be based upon the more gradual onset of the former and the absence of convulsion, though it may be difficult to distinguish from a vaso-vagal attack an epileptic attack with an aura of epigastric discomfort. Possibly the distinction is to some extent artificial Vaso-vagal attacks are distinguished from anxiety attacks by the prominence in the latter of the sense of anxiety and of motor restlessness, which is in marked contrast to the immobility which usually accompanies the former. Coronary thrombosis is likely to be attended by considerable precordial pain which persists for two or three days. In angina of effort, though dyspnœa and angor animi may be present, pain is a prominent symptom and the attacks, unlike vaso-vagal attacks, follow exertion.

Prognosis.

The attacks resemble those of epilepsy in their tendency to recur at irregular intervals over a number of years. There is no record of an attack having proved fatal.

Treatment.

The patient should as far as possible lead a quiet, regular life, avoiding indiscretions in diet, and an adequate daily evacuation of the bowels must be secured. The same sedatives which are of value in the treatment of epilepsy are useful, especially phenobarbital and bromide. In addition tincture of belladonna should be given in doses of 7 to 10 minims, according to the tolerance of the patient, and Gowers recommends liquor trinitrini in doses of $\frac{1}{2}$ to 1 minim. Ephedrine in $\frac{1}{4}$-grain doses is also useful. Whatever drugs are used should be given twice or thrice daily for a period of several months.

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5. TETANY

Definition: Tetany, or carpopedal spasm, is a form of muscular spasm beginning in, and sometimes remaining limited to, the peripheral muscles of the limbs. It is associated with an increased excitability of the neuromyone to all forms of stimuli. It is a symptom of a variety of disorders which either reduce the calcium content of the blood or increase its alkalinity.

Aetiology.

Noel Paton, Findlay, and others in 1910 observed that the symptoms of tetany following experimental removal of the parathyroids resembled those of guanidine intoxication and put forward the view that the latter was the cause of tetany. There is no evidence, however, that guanidine intoxication is the cause of tetany in man, and modern investigations of the metabolism of calcium and of the biochemistry of the blood have rendered it possible to reduce the *immediate causes of tetany to two. It is probable that in all cases* the patient is suffering from either a subnormal calcium content of the blood, or from an alkalosis, though a few conditions remain which have not yet been sufficiently investigated to enable them to be placed in either class. An attempt has been made to attribute all forms of tetany to calcium deficiency, on the hypothesis that alkalosis diminishes the amount of ionized calcium in the blood, even though its total calcium content remains normal. This at present, however, remains unproved, and there are indications that tissue anoxaemia may be of some importance.

Conditions characterized by a Subnormal Blood Calcium.

Parathyroid Deficiency. The important rôle of the parathyroids in *the metabolism of calcium and their influence upon the calcium* content of the blood are comparatively recent discoveries. Hyperparathyroidism due to a parathyroid tumour causes the blood-calcium content to rise above its normal figure of between 9 and 11 mg. per 100 c.c. Hypoparathyroidism leads to a subnormal blood-calcium content *which may be as low as 4 or 5 mg. per 100 c.c.*, and in such cases tetany may occur—tetania parathyreopriva. Hypoparathyroidism, which is rare, is usually the result of thyroidectomy but may occur spontaneously, a condition analogous to myxoedema.

Steatorrhoea. Fatty diarrhoea, when severe and of long duration, may lead to a fall in the blood-calcium content sufficient to cause tetany. Thus tetany may occur in sprue, in cases of so-called idiopathic steatorrhoea, and, exceptionally, in tuberculous enteritis.

The low blood calcium in such cases has been attributed to loss of calcium from the intestine in combination with fatty acids in the form of soaps. Recent investigations, however, suggest that the chief cause of the calcium defect is a failure to absorb vitamin D (Hunter)

Dietary Deficiency. Dietary deficiency appears to be the cause of tetany when this complicates rickets, osteomalacia, and hunger-osteopathy. The last two are characterized by a subnormal calcium content of the blood, which, however, only occurs in a proportion of cases of rickets. A deficiency of vitamin D in the diet is present in all three disorders, while in the last two the calcium intake may also be deficient.

Increased Demand for Calcium Pregnancy and lactation may cause tetany, owing to the increased demand which they make upon the calcium resources of the mother. The likelihood of tetany occurring is much increased when the intake of vitamin D and calcium is subnormal, as in osteomalacia.

Conditions characterized by Alkalosis

Alkalosis occurs when the ratio of acid to base in the blood, represented by the fraction $H_2CO_3/BHCO_3$, is diminished, with the result that the pH, normally between 7·3 and 7·5, rises This may occur in the following conditions:

Excessive Ingestion of Alkali. Overdosage with sodium bicarbonate may cause alkalosis and hence tetany, especially if the power of the kidney to excrete alkali is diminished by nephritis.

Hyperpnoea. Overbreathing, by washing out CO_2 from the blood, may lead to alkalosis and hence to tetany Tetany may thus be introduced by voluntary forced breathing, by hysterical hyperpnoea, or by hyperpnoea occurring as a result of disturbance of function of the respiratory centre, for example in encephalitis lethargica

High Intestinal Obstruction. It has long been known that tetany may complicate disorders associated with repeated vomiting—gastric tetany—and McCallum suggested that in such cases alkalosis was produced by a loss of acid from the body in the vomit Since, however, alkalosis may occur in cases of pyloric obstruction due to carcinoma of the stomach, in which the vomit may be free from acid, this hypothesis cannot be the whole explanation It has been shown experimentally that high intestinal obstruction in itself leads to a fall in the chloride content and a rise in the bicarbonate content of the blood.

Tetany of Uncertain Aetiology.

So-called idiopathic tetany occurs in epidemic form in some of the countries of central Europe, usually in the spring months. Workmen

are principally affected. Tetany has also been described as occurring in association with acute infections and poisoning by ergot, phosphorus, and morphine, and after the administration of chloroform or other anaesthetics.

Symptoms.

An attack of tetany is usually preceded by tingling sensations in the periphery of the limbs, especially in the hands. The attack itself consists of muscular spasm which develops spontaneously, but the intensity of which may be increased by external stimuli, such as manipulation of the limbs. In mild cases the spasm is confined to the hands and feet, or even to the hands. The tonic contraction of the interossei of the hands leads to a typical attitude—*la main d'accoucheur*. The fingers are slightly flexed at the metacarpophalangeal joints and extended at the interphalangeal joints. They are strongly adducted, and the thumb is similarly adducted and usually extended. The cause of the limitation of the muscular spasm in mild cases to the small muscles of the hands is unknown. Exceptionally, the fingers become flexed at all joints, and Rosett, in investigating the tetany produced by voluntary hyperpnoea, has shown that the limbs will become rigid in any posture in which they are previously fixed. The characteristic attitude of the feet is one of plantar flexion at the ankle and adduction of the toes.

In severe attacks the muscular spasm spreads to the proximal muscles of the limbs. In the upper limbs it predominates as a rule in the flexors of the elbow and in the adductors of the shoulder. In the lower limbs the knees are usually extended and the hips adducted. In such cases the muscles of the head may also go into spasm, the masseters closing the jaw and the angles of the mouth being retracted in a *risus sardonicus*. The eyes may be partly closed and the bulbar muscles may also be affected, especially those of the larynx. Dysarthria and dyspnoea may thus be produced. Spasm of the trunk muscles may also occur, leading to slight opisthotonos.

Though slight attacks of tetany are painless, considerable cramp-like pain attends the more violent spasms. Sweating and tachycardia and even rise of temperature may occur in severe attacks.

The increased excitability of the neuromyone is demonstrable in the response to certain tests, even in the absence of actual attacks of tetany. *Chvostek's sign* consists of a brisk contraction of the facial muscles in response to a light tap over the facial nerve in front of the external auditory meatus. Pressure upon the main artery supplying a limb or upon the peripheral nerves may precipitate an attack of tetany—*Trousseau's sign*. This test is simply applied by

means of the cuff of a sphygmomanometer. The response to electrical stimulation of the nerves is also abnormal, as Erb first demonstrated. There is increased excitability of the motor nerves, and when the galvanic current is employed a response is most readily evoked by the anodal closing current (*Erb's electrical reaction*). The ulnar nerve is the most convenient for this test. Bourguignon and Haldane have shown that during tetany induced by voluntary hyperpnoea there is an increase in chronaxy as determined by stimulation both of the nerve-trunk and of the motor point

In severe tetany generalized epileptiform convulsions associated with loss of consciousness may occur, but are rare. I have met with transitory defects of the visual fields resembling those associated with migraine as a complication of tetany These were probably produced by spasm of the smooth muscle of the arteries of the retina or visual cortex. Similarly bronchial spasm may occur The tendon reflexes are exaggerated during an attack of tetany if the muscular spasm is not too great to allow them to be elicited. Signs of organic disease of the nervous system are absent

Clinical Varieties of Tetany

Infantile Tetany. Infantile tetany is usually, if not always, due to rickets. It is not uncommonly associated with epileptiform convulsions. It is uncommon in its fully developed form, but spasm of the adductors of the larynx—laryngismus stridulus—is probably a manifestation of tetany. This occurs in attacks, beginning with dyspnoea due to difficulty of inspiration and terminating in a long-drawn inspiratory whoop.

Tetania Parathyreopriva. A patient suffering from tetany as a result of removal or destruction of the parathyroids is subject to attacks of muscular spasm which may last from a few minutes to several hours, but in addition, owing to the subnormal level of calcium in the blood, is constantly on the verge of an attack and may suffer chronically from stiffness of the fingers sufficient to interfere with occupations involving fine movements.

Tetany due to Hyperpnoea. When tetany is due to hyperpnoea the attack occurs only after a prolonged period of overbreathing, and soon comes to an end when the respiratory rate returns to normal.

Gastric Tetany. This form of tetany occurs as a sequel to prolonged vomiting, especially when this is a symptom of dilatation of the stomach. The muscular spasm occurs in attacks, as in the other varieties of tetany.

Tetany occurring as a symptom of other pathological states presents no special features.

3 L

Diagnosis.

The symptoms of tetany are so striking that they are not likely to be confused with other conditions. The onset of the muscular spasm in the hands and feet and the associated signs of increased neuromuscular excitability are pathognomonic of tetany. Tetanus is distinguished by the fact that in this disease muscular spasm, though subject to exacerbations, is constant and not, as in tetany, intermittent. Moreover, in tetanus the *main d'accoucheur* attitude does not occur and spasm of the masseters as a rule develops early, whereas in tetany this is a late symptom *occurring only in severe* attacks. Hysteria may be associated with tetany when the latter is produced by hysterical hyperpnoea. In addition hysterical muscular rigidity may simulate tetany. In hysteria, however, the typical attitude of tetany is as a rule absent, though I have seen one hysterical patient who had suffered from tetany as a child and who in later life reproduced the attitude of tetany as an hysterical symptom with remarkable accuracy. Other hysterical symptoms, such as anaesthesia, are usually to be found in such cases, and the patient's emotional reaction to his symptoms is characteristic.

In every case of tetany the underlying cause must be ascertained. This is usually easy if the common causes are borne in mind and appropriate inquiries are made. It is, however, always desirable that the pH and bicarbonate content of the blood-plasma and the calcium content of the serum should be ascertained, in order to determine whether the condition is due to a low blood calcium or to an alkalosis.

Prognosis.

Recovery from an attack of tetany is almost invariable, though death may occur in a severe attack, owing to laryngeal or bronchial spasm. The prognosis as to cessation of the attacks depends upon the nature of their cause.

Treatment.

In the treatment of tetany one must always take into account its underlying cause.

In tetany due to hypoparathyroidism the blood calcium may be raised by administering calcium lactate as a powder taken fasting in repeated doses up to a total of 10 to 30 grammes daily (Hunter) together with vitamin D. In severe cases parathyroid extract (parathormone) may be required in addition, the dosage (usually 10–15 units) being controlled by determinations of the blood calcium. A severe attack may be cut short by slowly injecting 20 c.c. of 5 per cent. solution of calcium gluconate intravenously.

In tetany due to steatorrhoea the intake of fat in the diet should be restricted to a minimum and the patient should be given irradiated ergosterol. This vitamin, with or without irradiation with ultraviolet light, is all that is required in the treatment of tetany associated with rickets, and the same treatment should be given in osteomalacia and when tetany occurs in pregnancy, together with calcium by the mouth and a diet rich in calcium. Parathyroid extract should not be given in these conditions, since it raises the blood calcium by withdrawing calcium from the bones. Attacks of laryngismus stridulus, if severe, can be cut short by the intramuscular injection of 1 gram of calcium chloride (Cameron) or by the inhalation of a little chloroform.

When tetany is due to alkalosis, this may be directly combated by the administration of ammonium chloride. This may be given by the mouth in doses of 1 gramme in a glass of water six or eight times a day. In cases of pyloric obstruction, 10 oz. of a 2 per cent. solution may be administered by the rectum. In addition the cause of the alkalosis must be treated and appropriate surgical treatment may be required in gastric tetany.

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6. MYOCLONUS

The term 'myoclonus' is applied to a brief, shock-like muscular contraction which may involve the whole muscle or may be limited to a small number of muscle-fibres. Myoclonus may be confined to a single muscle or may involve many muscles, either successively or simultaneously. Not infrequently contractions occur symmetrically in muscles on the opposite sides of the body. The contraction may be too slight to cause movement of a segment of the limb or may cause such violent movements as to throw the patient to the ground. The contraction never involves groups of muscles which are normally synergically associated, nor does it as a rule affect mutually antagonistic muscles.

The situation of the disorder of function responsible for myoclonus has been much discussed. Some myoclonic movements appear to be disturbances at a low level of the nervous system, the neural discharge which excites the muscular contraction being probably confined to the lower motor neurone. This seems to be the case in facial myoclonia. On the other hand, widespread synchronous myoclonus may be produced by lesions in the neighbourhood of the olive, and electro-encephalography has shown that the myoclonic movements which occur in epileptics and in sufferers from myoclonus epilepsy are excited from the cerebral cortex.

Myoclonus is, therefore, a symptom which may be produced by a variety of different lesions, and in some cases the nature of the underlying disorder of function is still obscure. The classification of varieties of myoclonus is, therefore, necessarily somewhat arbitrary.

VARIETIES OF MYOCLONUS

(1) Facial Myoclonus.

See p. 172.

(2) Hiccup.

Hiccup consists of a brief spasm of the diaphragm, associated with adduction of the vocal cords, brought about by the forcible inspiration of air into the lungs. Usually the intervals which separate successive spasms last from a quarter of a minute to a minute or longer. Exceptionally, hiccup occurs very frequently, even as often as 120 times a minute. Paroxysms of hiccup may last for days, interfering with sleep and causing profound exhaustion, which may even terminate fatally. The principal causes of hiccup are:

(i) *Reflex Hiccup*. Hiccup may be reflexly excited by stimulation of sensory nerves over a wide area, but especially from the vagus and the phrenic nerve itself. It may follow irritation of the lower end of the oesophagus and the stomach by food which is hot or highly seasoned. Gastric distension is also a common cause, and the stomach may be both distended and irritated, for example, with alcoholic drinks. Laughing causes hiccup, partly by enhancing the excitability of the diaphragm and partly by leading to air-swallowing. Hiccup may also be reflexly excited by *gastritis*, by *conditions leading to* abdominal distension, by irritation of the upper part of the peritoneum, through local or general peritonitis, and by lesions of the diaphragm, for example, diaphragmatic pleurisy. I have known painful hiccup produced by the invasion of the diaphragm by a chronic gastric ulcer.

(ii) *Irritation of the phrenic nerve*, by mediastinal neoplasms, enlarged mediastinal glands, and aneurysm of the aorta, may cause hiccup.

(iii) *Central Lesions.* Hiccup may be produced by lesions of the cervical region of the spinal cord in the neighbourhood of the third and fourth segments, from which the phrenic nerve originates, and an inflammatory lesion in this situation is probably the cause of hiccup in encephalitis lethargica and of epidemic hiccup. Hiccup may also follow lesions of the medulla and lesions giving rise to increased intracranial pressure which possibly operate indirectly by disturbing medullary function.

(iv) *Other causes* of hiccup include uraemia and hysteria.

Treatment.

The first step in the treatment of hiccup is to remove the cause, if this is possible. Symptomatic treatment may begin with homely remedies such as holding the breath, inducing sneezing by means of snuff or pepper, and taking a minim of oil of peppermint on a lump of sugar. When gastric irritation is the cause the stomach may be washed out. Otherwise the treatment is sedative. Immersion in a bath as hot as the patient will stand it for twenty minutes or half an hour is sometimes successful. Full doses of sedatives should be given. Phenobarbital and nembutal are the most useful. Sometimes 1/20th of a grain of apomorphine will stop an attack. In severe cases it will be necessary to resort to morphine or the inhalation of chloroform or to inject the phrenic nerves with novocain.

(3) Myoclonus in Encephalo-myelitis.

Myoclonus is a somewhat uncommon symptom of encephalitis lethargica. It has occurred with special frequency in some epidemics (see p 432). It may also occur in herpes zoster, especially in those cases in which there is evidence that the infection has spread in the spinal cord beyond the first sensory neurone (see p. 466).

(4) Palato-pharyngo-laryngo-oculo-diaphragmatic Myoclonus.

This syndrome, as its name implies, is characterized by the synchronous occurrence of a rhythmical myoclonus of the soft palate, pharynx, larynx, eyes, and diaphragm and sometimes of other muscles. The distribution of the myoclonus may be unilateral or bilateral. The palatal movement has been described as 'nystagmus of the soft palate'. The rate of the movements varies from 80 to 180 to the minute, and is usually about 120 to 130 contractions to the minute. It is uninfluenced by drugs, and apparently by sleep, but may be inhibited at first by voluntary effort, and disappears if paralysis supervenes in the myoclonic muscles.

This form of myoclonus is usually encountered after middle life, the commonest cause being a vascular lesion of the brain-stem, but other causes include disseminated sclerosis, aneurysm of the vertebral artery, and tumour of the cerebellum and mid-brain. According to Guillain (1937-8) the essential lesion is one which damages the olivo-dentate system, that is the principal olivary nucleus, the olivo-dentate fibres, and the dentate nuclei of the cerebellum. Unilateral myoclonus is the result of a lesion affecting the ipsilateral dentate nucleus and the opposite olive.

(5) Paramyoclonus Multiplex.

The term 'paramyoclonus multiplex' and its synonyms, myoclonus simplex and essential myoclonia, should be reserved for the syndrome first described by Friedreich in 1881 and characterized by the onset during adult life of frequent myoclonic muscular contractions. These are most frequently observed in the biceps, triceps, and supinator longus in the upper limbs and in the quadriceps, and to a less extent in the adductors of the hip, biceps, and semitendinosus in the lower limbs. The muscular contraction involves the whole muscle and occurs regularly with a frequency varying from ten to fifty times a minute. It does not as a rule produce movement of a limb segment, and though it affects symmetrically muscles on the two sides of the body, these do not contract synchronously. The myoclonic movements disappear during sleep and on voluntary contraction of the affected muscles. The electrical reactions of the muscles are normal, sensation is unimpaired, and the only associated abnormality is an exaggeration of the tendon reflexes. The disorder is a chronic one which does not threaten life, and in some cases recovery occurs. Its pathological basis is unknown. According to Muskens it is sometimes hereditary. Treatment with sedative drugs should be carried out on the same lines as for epilepsy.

(6) Myoclonus Epilepsy.

Myoclonic contractions are common in patients suffering from idiopathic epilepsy, occurring between the epileptic attacks and usually becoming intensified before the fit occurs. In addition epileptic attacks have been described in patients regarded as suffering from paramyoclonus multiplex, though it is difficult to say on what grounds such cases are distinguished from idiopathic epilepsy with myoclonus. The term 'myoclonus epilepsy' is best reserved for the rare but well-defined syndrome first described by Unverricht in 1891, and later carefully studied by Lundborg. Myoclonus epilepsy thus defined is usually familial and occurs in several siblings. In the family described by Unverricht, sixteen pregnancies resulted in five

affected and five normal siblings, five miscarriages, and one child who died in infancy. Mott has described the disorder in four siblings Myoclonus epilepsy appears not to have occurred in more than one generation of a sibship, but the uncle of Mott's patients was an epileptic, and a patient of my own had an epileptic brother. Apart from the probability that inherited predisposition plays a part in aetiology, the cause of myoclonus epilepsy and its relation to the ordinary form of epilepsy remain obscure. Grinker and his collaborators (1938) have demonstrated by means of electro-encephalography the cortical origin of the myoclonic discharges and their transition into the generalized attack. Mott and Jacqun and Marchand have described degenerative changes in cortical ganglion cells

The onset of symptoms usually occurs between the ages of 6 and 16, usually when the patient is about 10, development up to that point having been normal. Generalized epileptiform attacks with loss of consciousness appear first, and, to begin with, frequently occur only at night After several years the characteristic myoclonic contractions develop These are shock-like muscular contractions simultaneously involving symmetrical muscles on both sides of the body, sufficiently strong to produce movements of the limb segments They involve the muscles of the face, trunk, and of both upper and lower limbs. They disappear during sleep and are intensified by emotional excitement. They often increase in severity before a generalized epileptic attack but are not attended by loss of consciousness. In the face, myoclonus may occur in the ocular muscles, the lips, and the tongue, interfering with speech and with swallowing. In the limbs the flexors are more often attacked than the extensors Writing may become impossible, and sudden contractions of the flexors of the lower limbs when the patient is standing or walking may throw him violently to the ground After some years, during which myoclonic and epileptic attacks are associated, a progressive dementia develops and the patient passes into the third stage of the disease, in which the epileptic attacks tend to disappear, though myoclonus continues. Dysarthria and dysphagia increase, and death follows progressive cachexia

Treatment is merely palliative. The usual treatment of epilepsy may control the generalized epileptic attacks, but has less influence upon the myoclonus.

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7. ACROPARAESTHESIAE

The term acroparaesthesiae is applied to unpleasant tingling sensations occurring, as the name implies, in the extremities. Although such sensory disturbances are common symptoms of organic nervous disease, the term acroparaesthesiae is reserved for their occurrence in the absence of organic lesions. As such they are found almost exclusively in middle-aged women of the working class, developing usually about the menopause. The tingling usually begins in the fingers, both hands being affected symmetrically, and may spread to involve the whole of the upper limbs. The lower limbs are less often affected. The symptom is especially troublesome at night, when the patient is in bed. It may interfere with sleep and is not uncommonly associated with slight depression. Physical signs of organic disease are absent. The cause of the condition is unknown, but it is probable that the abnormal sensations originate in the small blood-vessels, and they may be the result of early atheromatous degeneration.

Acroparaesthesiae must be distinguished from paraesthesiae occurring as early symptoms of organic disease, especially subacute combined degeneration and polyneuritis. In these conditions, however, sensory loss and reflex changes are likely to be present.

The most effective treatment consists of sedatives, such as phenobarbital and bromide, combined with a vasodilator, such as liquor trinitrini in $\frac{1}{2}$- to 1-minim doses, and small doses of thyroid extract, e g gr. $\frac{1}{4}$ twice daily.

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PSYCHOLOGICAL MANIFESTATIONS OF ORGANIC NERVOUS DISEASE

THE growth of medical psychology has rendered it necessary to restrict the scope of the psychological section of a text-book of neurology. Neither psychiatry nor psychotherapy, as such, fall within the province of neurology. Nevertheless, since the brain is the organ of the mind the neurologist has unique opportunities of observing the effects of nervous disease upon the mental functions and in particular of studying disorders of perception, memory, and emotion. He is also concerned with the psychoses and psychoneuroses in the diagnosis of organic nervous disease. This section, therefore, deals with psychological medicine primarily from the standpoint of the neurologist.

1. ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

The principal difference between the human and the sub-human brain consists in the great development of the cerebral cortex in man. The cortex is, in the first instance, an end station at which are received nervous impulses derived from the eyes, the ears, and other sensory organs. The corresponding regions of the cortex are linked by association paths by means of which the sensations which form the raw material of perception evoke memories and become enriched with meanings which can be communicated to others by means of speech, writing, and gesture. The function of the cerebral cortex, therefore, as Head pointed out in relation to sensation, is primarily discriminative and the massive development of the cortex in man compared with that in the lower animals is paralleled by the great *enhancement of the range of his discriminative faculties*, which has occurred in spite of there having been little improvement, and in some cases an actual retrogression, of his sensory acuity.

By contrast there is far less difference between man and the lower animals in respect of the development of subcortical centres, and in particular of the thalamus and hypothalamus. It is these regions of the brain, basal alike in situation and in function, which are intimately concerned with the affective element in feeling, with the emotional and instinctive life, and the regulation of the autonomic *nervous system and to some extent of metabolic and endocrine* function. The brain, however, works as a whole and there is a constant interplay between cortical and subcortical functions.

Perception evokes emotion and, conversely, emotion provides the interest which activates perception.

There is another aspect, however, of the relationship between the cerebral cortex and subcortical function. Discrimination, the function of the co-cortex, implies inhibition, for, if an organism is to react appropriately to a stimulus, inappropriate modes of reaction must be simultaneously inhibited. This is true even at the level of a simple reflex arc, it is far more essential when the range both of potential stimuli and of potential reactions has been so greatly enlarged by the development of the cerebral cortex. The cortex, therefore, acquires inhibitory functions as the complement of its discriminative functions. As Head and Holmes have pointed out, the phenomena of thalamic over-reaction seem to imply that normally the cerebral cortex exerts an inhibitory influence over the optic thalamus. The work of Bard and of Fulton and Ingraham has shown that the cortex exerts a similar inhibitory influence over the hypothalamus, and that animals from which this higher control has been removed exhibit paroxysmal and massive motor and autonomic reactions, such as are normally linked with an emotion like rage.

It has long been believed that the frontal lobes play a particularly important part in the mental life. Penfield and Evans (1935) found that the maximum amputation of the right or left frontal lobe produced little change in the mental life except for some impairment of those processes necessary for planned initiative, and Jefferson (1937) concluded from 8 cases of unilateral frontal lobectomy that the role of the frontal lobes in the mental life is quantitative rather than qualitative. Rylander (1939) reported 32 cases of operation on the frontal lobe. Emotional changes consisted of diminished inhibition of affective responses and a tendency to euphoria, less often to depression. Changes in psychomotor activity took the form either of restlessness or of lack of initiative and interest. In the intellectual life the more automatic forms of intelligence were relatively well preserved, together with attention and memory, but the higher forms of reasoning, thinking in symbols and judgement had deteriorated. All of these features were exhibited by Brickner's (1936, 1939) patient who was observed for eight years after bilateral frontal lobectomy.

In the interpretation of mental symptoms the distinction between positive and negative symptoms enunciated by Hughlings Jackson proves as valuable as in the somatic sphere. A disorder of function may manifest itself in negative symptoms which are the functions lost, and positive symptoms which are the outcome of the resulting uncontrolled or disordered activity of parts of the nervous system which remain active. It will be convenient to consider first the

nature and interpretation of mental symptoms produced by organic nervous disease, and then to turn to those combinations of symptoms or 'pattern reactions' which, though to some extent variable, constitute well-defined clinical pictures.

2. DISORDERS OF PERCEPTION

Defect of perception in its simplest form is due to a lesion of the primary sensory pathways concerned. The effects of such lesions are described elsewhere. At the next higher level the immediate sensory data are integrated with memories so that objects are perceived as endowed with meaning. Disorder of perception at this level leads to the various forms of agnosia (see p. 104).

Hallucinations.

An hallucination may be defined as a sensory impression commonly excited by an external stimulus, but occurring in the absence of such a stimulus. The simplest form of hallucination is one which is caused by the excitation of a cortical sensory area, e.g. the olfactory hallucinations caused by a lesion of the uncinate gyrus. The patient usually speedily detects the internal origin of such hallucinations. The teichopsia of migraine, for example, clearly move with the eyes and bear no constant relationship to the external world. Somewhat more complex hallucinations may occur as a result of a massive excitation of afferent fibres as, for example, when diminutive figures are seen by a patient with a tumour of the temporo-sphenoidal lobe.

The hallucinoses are abnormal psychical states of which hallucinations constitute the predominant feature. These are usually toxic in origin, such as febrile delirium, delirium tremens, acute alcoholic hallucinosis, the hallucinoses produced by drugs such as mescal, fly agaric, Indian hemp, cocaine, bromide, &c., but a comparable state occurs in certain individuals as an abnormal form of sleep. The hallucinations may be experienced within the realm of any form of sensibility and may be extremely elaborate.

The occurrence of hallucinations depends upon a disturbance of the mental processes by means of which we distinguish between the objective and the subjective in our experience. In normal adult waking life there is no difficulty in making this distinction, indeed it is already made. Certain images are externalized; others are not. In childhood and among primitive races the distinction is less clearcut. During dreams images of subjective origin are externalized and dreams have all the characteristics of hallucinations. Although the whole content of the dream is a product of the subconscious mind

certain images are still experienced as external to the ego, while other mental states are still experienced as subjective. Moreover, an external stimulus such as a sound, on reaching consciousness during sleep, may become the nucleus of an hallucination, being misperceived. In the hallucinoses the mental state of the patient is similar to that of a person in a dream and images of subjective origin are externalized, but since he is awake the resulting hallucinations mingle with a confused perception of the external world, and external stimuli, being more plentiful than during sleep, readily become the basis of illusions. Moreover, the patient is not, like a sleeping person, a passive percipient, but may respond by action to the illusory events which he witnesses. In certain states, such as mescal poisoning, perception of time and space may be disordered and synaesthesiae may occur, as, for example, when the perception of musical notes is accompanied by hallucinations of colour. Sleep hallucinosis forms a link between normal dreaming and the hallucinoses occurring in toxic states. Hallucinations in schizophrenia seem to be the product of a disturbance of mental function similar to that occurring in the hallucinoses just described.

Hallucinations are not very commonly the result of focal cerebral lesions except those of a crude kind already described as due to the excitation of cortical sensory areas, but may occur in states of confusion produced by intracranial tumours or vascular lesions.

Delusions are usually regarded as distinct from hallucinations, a delusion being defined as an erroneous belief which cannot be corrected by an appeal to reason and is not shared by others of the patient's education and station. Nevertheless, a delusion, though clearly a more complex mental state than an hallucination, involves a similar failure to distinguish between subjective and objective elements in experience. Delusions appear to be frequently the outcome of a perverted attempt to find a reason for an emotional state. Thus the grandiose delusions of a patient with general paralysis may be a rationalization of his euphoria. Apart from the dementias, delusions are not often encountered in organic neurology.

3. DISORDERS OF MEMORY

Memory may be defined as the power to retain and recall past experiences. A little reflection, however, will show that memory thus defined includes functions of differing complexity. Perhaps the simplest form of memory is that involved in remembering a series of digits or a passage of meaningless jargon. In such an act of recollection or mechanical memory there is little emphasis upon the 'pastness' of what is recollected. The emphasis is rather upon the

persistence into the present of a series of acts which have become habitual, perhaps through repetition. In such an act of remembering there is nothing more than the three fundamental elements of memory, registration, retention, and recall. Compare this, however, with the recollection, evoked by a place or a scent, of a single past experience fraught with strong emotion. Such an act is initiated by an associative process and there is considerable emphasis upon the 'pastness' of the experience by contrast with a present in which it is no longer occurring. Moreover, of two such episodes in the past one is remembered as having been experienced prior to the other, so that arising out of the function of memory is the experience of a personal past time as an extended dimension in which past experiences bear a constant and linear relation to each other. Furthermore these past experiences are all felt as being the experiences of the same person, hence it follows that memory is essential to the experience of personal identity.

There is also a function of memory which seems to be intermediate between the reproduction of a passage of jargon and the recollection of an isolated incident. This is the recall of an image built up as a result of repeated experiences as, for example, that of a house or a person with whom one is familiar. A similar function of remembering enters not only into the act of representing to oneself the familiar house or face in its absence, but also into the act of recognizing it when it is presented to one again.

The following table (Gillespie) enumerates the factors involved in remembering and the conditions in which they may become disordered. Loss of memory is known as *amnesia*.

Factors in remembering	*Conditions in which these factors are interfered with or appear in isolation*
(a) Registration	Acute organic reaction type (delirium); manic excitement (inattention); hysteria (global inattention)
(b) Retention	Organic reaction type in general
(c) Recall	
(1) simple and elementary	Organic reaction type (severe degree)
(2) as a voluntary act	Psychogenic conditions, e.g., hysteria; certain forms of organic reaction type, e.g., trauma to the head; Korsakow's psychosis; epilepsy
(d) Time sense	Various psychoses with depersonalization(?); Korsakow's psychosis (amnestic symptom-complex)
(e) 'Pastness'	Epilepsy (déjà vu); anaesthetic states

Factors in remembering   *Conditions in which these factors are interfered with or appear in isolation*

(f) *Associations determined by* $\begin{cases} \text{sense organs} \\ \text{appetites} \\ \text{instincts} \\ \text{interests} \end{cases}$ $\begin{cases} \text{Organic reaction types} \\ \text{in general; psychogenic} \\ \text{conditions} \end{cases}$

(g) Imagery ('extracted   Korsakow's psychosis; early senile dementia
     images of Bartlett)

(h) Personal identity   Hysteria; *depersonalization in various psy-*
     (awareness of)   *choses*

(a) *Registration*. Defects of registration are usually due to disordered attention, such as occurs in severe psychotic states and in delirium.

(b) *Retention*. Failure of retention is probably the principal factor in the defect of memory which is a symptom of diffuse organic cerebral disease, such as arteriosclerosis and head injury. It is characteristic of such states that the remote past is remembered while the more recent past is forgotten. Failure of retention is certainly a factor in Korsakow's psychosis, though probably not the only factor responsible for the defective memory.

(c) *Recall*. It may be difficult to distinguish between a defect of retention and a defect of recall, the tendency being sometimes to attribute to lack of retention a difficulty in remembering which is actually due to lack of recall. This applies to retrograde amnesia in some cases. For example, during an interval of consciousness shortly after a head injury the patient may be able to describe how his accident occurred, though later he may state that he can remember nothing about it. He may further fail to recollect it when it is described to him, although the memory may be recoverable under hypnosis. If a patient fails to remember an episode, but can recognize it as having occurred when it is described to him, the amnesia is clearly due to a defect of recall and not of retention. Simple fatigue may be responsible for a defect of recall as a cause of amnesia. The psychological function of repression also operates as a factor inhibiting recall. Memories repressed include those which are painful in a crude sense, having been the cause of physical or emotional shock when the events occurred, or they may be repressed as being incompatible with the moral judgements which express the ideals of *the conscious self. Repression is thus a form of psychological dis-*sociation which is seen in an extreme form in cases of multiple personality. The simplest example of this is the fugue, an episode in which an hysterical person loses his sense of personal identity and wanders away from home for days or, rarely, for longer periods and on recovery has no recollection of the events of the fugue.

The patient may be able to recall them, however, under hypnosis. Such individuals may be regarded as dual personalities neither of which has access to the memories of the other. More complicated memory relationships may occur in persons with three or more personalities.

(d) *The Time Ordering of Experience.* As already stated the experience of a personal time is based upon memory and will be defective when memory is impaired as in Korsakow's psychosis.

(e) '*Pastness*'. Gillespie employs this term for the quality in virtue of which a past experience is recognized as past. Whatever its basis, the existence of such an element in memory is shown by the fact that it may become inappropriately attached to a present experience, which is then felt to have been experienced before. This false sense of familiarity, the *déjà vu* phenomenon, though not uncommon in normal people, is particularly characteristic of epileptic attacks originating in the uncinate gyrus. This region of the brain appears to be closely linked with the function of memory. The peculiar potency of the olfactory sense in evoking memories is well known. Uncinate attacks, as Wilson showed, may cause, in addition to the characteristic olfactory hallucinations and motor accompaniments, four varieties of memory disturbance: (1) the *déjà vu* phenomenon, (2) a sense of unfamiliarity attaching to familiar surroundings, (3) an intense revival of a long past experience, or (4) the reproduction in memory of long periods of the patient's past life.

(f) *Associative Functions.* Loss of associative functions probably plays an important part in contributing to defect of memory in diffuse organic conditions and in psychogenic amnesia. Association with a repressed idea may be the cause of amnesia for another idea which, in itself, does not appear to be a source of emotional stress.

(g) *Imagery.* The contribution of memory to the construction of images has already been described. It is difficult to isolate this element in remembering, clinically, but it would seem to be an important factor in recognition and is likely to be impaired in conditions in which the patient fails to recognize familiar objects, the various forms of agnosia.

(h) *Personal Identity.* The loss of the sense of personal identity may be due either to a severe disintegration of the highest mental functions, such as occurs in advanced dementia, or to hysteria, in which long periods of the past life, even the whole of it, may be the subject of amnesia. In hysterical infantilism, however, the patient usually preserves the power of speech and ordinary adult habits, thus exhibiting one of the discrepancies so characteristic of hysteria.

Tests of Memory.

It will be clear from what has been said that the function of remembering cannot be adequately tested by means of the ordinary simple tests which usually investigate the patient's power to retain and recall a series of digits or similar data. Inquiry must also be made into the patient's power to recall the events of his past life, both remote and recent, as well as his capacity for mechanical memory as illustrated by the recollection of passages learnt by heart. Other tests designed to investigate other functions of memory described above will suggest themselves in particular cases.

KORSAKOW'S PSYCHOSIS

The characteristic feature of Korsakow's psychosis is a certain type of amnesia. The patient has a gross defect of memory for recent events so that he has no recollection of what has happened even half an hour previously. He is disorientated in space and time and he fills the gaps in his memory by confabulating, that is by giving imaginary accounts of his activities. Thus a bedridden patient will describe a walk which he asserts he has just taken.

It has been thought that the amnesia of Korsakow's psychosis was due primarily to a defect of retention, but this is probably not the case, since the response to retention tests may be fairly satisfactory and it has been observed that a patient who has recovered from Korsakow's psychosis may recollect events after his recovery that he did not appear to notice at the time. Some defect of retention, however, is probably present in severe cases, but Gillespie suggests that the main factor in the memory disturbance may be a failure to extract from the mass of perception the images necessary for memory. The defect of appreciation of time is secondary to the amnesia.

Although Korsakow's psychosis is seen typically in chronic alcoholism, associated with polyneuritis, it may be the result of very varied pathological agencies. Other toxic or deficiency diseases may produce it, such as arsenical polyneuritis, pellagra, and subacute combined degeneration. It may also occur in patients suffering from cerebral arteriosclerosis, senile psychoses, and intracranial tumour. Though it is usually encountered during the phase of increased intracranial pressure due to intracranial tumour, I have known it follow the sudden lowering of pressure caused by the removal of a subtentorial tumour.

The treatment of Korsakow's psychosis is that of the underlying disorder. (For prognosis and treatment in alcoholism see pp. 667–9.)

4. DISORDERS OF MOOD

As has already been stated, the thalamus and hypothalamus appear to be the centres concerned in the registration of emotion and the integration of the accompanying bodily changes It is to disorders of this mechanism and of its relationship with higher levels of the nervous system that we must look for the explanation of disorders of mood occurring as a result of organic nervous disease

1 *Emotional Instability.*

Emotional instability or lability is a very common symptom of nervous diseases, *especially of those in which the lesions are diffuse.* The patient is easily moved by almost any form of emotion. He is *easily irritated or angered, easily becomes apprehensive, is readily* depressed or reduced to tears. Less often, he experiences pleasurable emotion with abnormal facility and is readily moved to laughter. Emotional instability of this kind is commonly encountered after head injury and in elderly patients with cerebral arteriosclerosis. It is frequently present in the early stages of dementia, how-ever produced, and *is highly characteristic of the later stages of* disseminated sclerosis. The animal experiments already quoted suggest that this exaggerated emotional reactivity common to so many disorders is the result of an impairment of the control which higher levels normally exercise over the thalamus and hypothalamus.

2. *Impulsive Disorders of Conduct.*

The emotional instability described in the previous paragraph does not usually lead to disorder of conduct, perhaps because conduct is normally more strongly inhibited than feeling. Exceptionally, however, impairment of higher control releases emotions which pass into action. This most often happens in children or adolescents in whom the control of impulsive action, which it is the object of education to impose, is as yet incomplete. The misdemeanours and acts of violence sometimes committed by children and adolescents who have had encephalitis lethargica are examples of this, and similar acts may be committed by epileptics, either before an epileptic attack or in the phase of post-epileptic automatism.

3. *Emotional Apathy.*

A general loss of emotional responsiveness without a proportionate intellectual deterioration is most characteristically seen in association with Parkinsonism due to encephalitis lethargica. In view of the known predilection of the virus of this disease for the diencephalic grey matter, it is reasonable to attribute the apathy to injury to the centres concerned in the emotional life. A similar picture is seen

associated with mental deterioration in the later stages of dementia from any cause. Here it is probable that the apathy is in part, at least, secondary to the deterioration of thought and perception. The apathetic patient loses all his former interests and affections and, lacking the drive of the instinctive life, he becomes incapable of effort and sinks into a vegetative existence.

4 Euphoria.

Euphoria is the term used to indicate a mood characterized by feelings of cheerfulness and happiness, a sense of mental well-being. Transitory euphoria is induced in many people by the consumption of alcohol. As a prevailing mood, it is seen most characteristically in disseminated sclerosis. Many sufferers from this disease remain persistently serene and happy in spite of their increasing physical disabilities. Euphoria is also encountered occasionally in patients with intracranial tumours, especially when the tumour is situated in the temporal lobe or, less frequently, in the frontal lobe or corpus callosum. Euphoria is not uncommon also in general paralysis and is the predominating emotional state in the milder degrees of maniacal excitement. The psycho-physiological basis of euphoria is little understood.

5. Depression.

Depression may be regarded as the opposite of euphoria. It is a mood of dejection and gloom for which frequently the patient can offer no explanation. It is encountered in a variety of states. It is sometimes produced by infections, especially influenza, and the bacillus coli. It may be a reaction to an adequate external cause, such as failure or bereavement, or a neurotic reaction to internal difficulties. In sufferers from cyclothymia depression is liable to occur as a recurrent disorder of mood, sometimes alternating with phases of excitement, though often these are no more than a mild general sense of elation. In cyclothymic individuals the depression is likely to be associated with some mental retardation, manifesting itself in a difficulty in concentrating, and with insomnia and loss of appetite. Depression also occurs as the predominant feature of involutional melancholia, in which it is often associated with agitation. Patients suffering from psychotic depression in a severe form not uncommonly have delusions of guilt or of a hypochondriacal nature. Depression is a mood which is common in patients suffering from organic disease of the brain. This may be in part a natural reaction to their disabilities and it is most likely to occur in individuals of a cyclothymic temperament in whom the nervous disease may be regarded as having released a pre-existing tendency to depression. Thus we encounter

depression commonly after head injury, in a minority of patients suffering from disseminated sclerosis, and sometimes in patients with intracranial tumour or general paralysis.

6. *Anxiety.*

Fear is the emotional reaction to an imminent danger, anxiety is the reaction to a possible future danger—fear linked with anticipation. Anxiety may be produced in a variety of ways. It may, of course, be a normal emotional reaction. It may be the effect of certain toxins which appear to stimulate directly the nervous centres concerned. These are all toxins which have a stimulating effect upon the sympathetic nervous system, namely, adrenaline, ephedrine, benzedrine, nicotine, and thyroxine. Anxiety may be the *prevailing mood in patients suffering from organic disease of the brain*, for example, following head injury, and it is then probably in part the outcome of diminished control of emotional reactions by higher centres and in part a reaction to the disability produced by the injury or disease Fear may be very evident in delirious states, when it appears as the reaction to terrifying hallucinations, and may be linked with depression in involutional melancholia. In very many cases, however, anxiety is psychogenic—that is, it is a symptom of neurosis.

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5. DEMENTIA

Dementia is the term applied to a deterioration in the mental functions manifesting itself primarily in thought and memory and secondarily in feeling and conduct. It may be produced by a large number of pathological agencies and the clinical picture varies somewhat according to the previous temperament of the patient, the age of onset, the localization, rate of progress, and nature of the causal disorder.

Symptoms.

1 Judgement and Reasoning.

The earliest disability is often an impairment of judgement and reasoning manifesting itself in a failure to grasp the meaning of a situation as a whole and hence to react to it appropriately. At this stage a man's *business judgement begins to fail, though in the semi-automatic activities of life no defect may be noticed.*

2. Memory.

Memory becomes impaired, the recollection of recent events suffering more than that of early periods of life (see p. 894). Even when both are grossly defective, mechanical memory may remain for a time. In more severe stages of dementia, defect of memory linked with defective perception leads to disorientation in space and time.

3 The Emotional Life.

Although in some patients the emotional life is little disturbed, in others impairment of higher control leads to emotional instability which finds expression in irritability and impulsive conduct. Acts of *violence, alcoholic excess, and sexual aberrations are thus explained.* The prevailing mood may be one of euphoria, with hilariousness and hyperactivity, depression, anxiety, or maniacal excitement, and will be influenced by the pre-existing psychological constitution. In the late stages, the patient is apathetic.

4. Delusions.

Delusions are the outcome of emotional disorder, associated with impairment of judgement and defective appreciation of reality. Delusions centred on the self are likely to be grandiose in a state of euphoria and self-condemnatory or hypochondriacal in a state of depression. Delusions regarding others are often hostile and express fear, suspicion, or jealousy.

5. *Care of the Person.*

In the later stages of dementia the patient becomes careless in dress and in personal cleanliness and finally incontinent. This may be attributed at first to a decay of the self-regarding sentiment and later also to the lack of perception.

6. *Speech.*

In the later stages also, speech undergoes a progressive disintegration. Though the forms of aphasia caused by focal lesions of the brain may be present in dementia, there is also a destruction of the speech function as a whole, so that speech becomes increasingly meaningless and ends in jargon or isolated words or phrases, 'logoclonia'. Agnosia and apraxia may also develop.

7 *Physical Concomitants.*

The condition of the somatic nervous functions will depend upon the causal disorder, but, whatever the cause, there is usually a general physical deterioration with loss of weight and depression of endocrine function.

Aetiology.

The causes of dementia are:

(1) Syphilis—general paralysis, cerebral meningo-vascular syphilis, &c.

(2) Cerebral arteriosclerosis.

(3) The presenile dementias—a mixed group of degenerative diseases of unknown origin—Pick's disease, Alzheimer's disease (presbyophrenia), Jakob-Creutzfeld's disease, Huntington's chorea.

(4) Intracranial tumour.

(5) Non-syphilitic inflammatory diseases—encephalitis (various forms), intracranial abscess, meningitis, disseminated sclerosis

(6) Intoxications and deficiency diseases—alcoholism, drug addiction, uraemia, subacute combined degeneration, pellagra

(7) Dementia supervening upon other chronic psychotic states

(8) Epilepsy.

(9) Injury to the brain.

Since in most of these disorders the dementia is an inconstant and sometimes a rare symptom, an account of them must be sought in the appropriate sections of this book. The presenile dementias, however, which, with the exception of Huntington's chorea, are predominantly mental disorders, are most conveniently considered at this point, and also will provide an opportunity of considering the diagnosis of dementia.

THE PRESENILE DEMENTIAS

Alzheimer's Disease.

Alzheimer's disease is a progressive cerebral degeneration with the pathological picture of senility occurring in middle life. The essential lesion is a diffuse degeneration of the cerebral cortex involving all its layers and most marked in the frontal lobes. The basal ganglia and the cerebellum escape. The brain is atrophic. Histologically, besides degeneration of the ganglion cells of the cortex there is a profusion of senile plaques in the cortex. These are silver-staining masses, often ring- or star-shaped, and probably of neuroglial origin. In addition, there are intraneural fibrillary tangles. These changes are regarded as characteristic of senile degeneration of the cortex. Their occurrence in middle age is unexplained, but there seems no doubt that Alzheimer's disease is essentially premature cerebral senility.

Alzheimer's disease develops between the ages of 40 and 60. The symptoms are those of a progressive dementia with apraxia and speech disturbances. The onset is insidious. In the early stages the patient suffers from loss of memory and becomes careless in dress and conduct. Epileptiform attacks may occur. Speech becomes slurred, and there is difficulty in recalling words. As the disease progresses there is complete disorientation. The patient recognizes none of his friends, becomes restless, and may wander about. A progressive deterioration takes place in the faculty of speech, which, from paraphasic talkativeness, becomes reduced to isolated words and phrases, so-called logoclonia. Movements become stereotyped and the sucking reflex is often elicitable. Spastic contractures usually develop. The duration of the disease is from one and a half to thirteen years. Treatment does not influence its course. (For the diagnosis of dementia see p. 903.)

Pick's Disease.

Synonym: Circumscribed cortical atrophy.

This condition is characterized by circumscribed atrophy of the cerebral cortex, usually confined to the frontal and temporal regions. The upper three cortical layers are principally affected, exhibiting chromatolysis and disappearance of ganglion cells. There is some glial increase in the atrophic areas, but senile plaques and intraneural fibrils are absent and arteriosclerosis plays no part in causation. The cause of the disease is unknown. It may be toxic in origin or a form of primary degeneration developing in middle life. Multiple cases have been described in one sibship. The age of onset is usually between 50 and 60, and the disease has a duration of from three

to twelve years, always terminating fatally. Females are said to be affected more often than males. It is characterized by a progressive dementia and aphasia. Restlessness and loss of normal inhibitions are prominent in the early stages. The patient is often voluble and tends to make jokes and puns. At first the more abstract intellectual functions suffer, but the more concrete type of behaviour is well-preserved and the patient emotionally accessible. Later, mental dullness becomes pronounced and epileptic attacks may occur. Speech is reduced to a few stereotyped phrases. In the terminal stages there is much loss of weight, and the patient becomes bed-ridden and tends to develop contractures.

The Diagnosis of the Cause of Dementia.

The cause of dementia is sometimes obvious, as when the condition follows head injury, acute encephalitis, epilepsy, or chronic alcoholism. Dementia of syphilitic origin, whether due to general paralysis or meningo-vascular syphilis, is associated with characteristic serological reactions and usually with abnormal physical signs in the nervous system. In cases of intracranial tumour the history is usually short and the course of the dementia steadily progressive. The diagnosis is easy if symptoms and signs of increased intracranial pressure are present. In their absence an encephalogram is often necessary. Arteriosclerotic dementia is usually encountered after the age of 60. The onset is usually insidious and there is often a history of focal cerebral vascular lesions, slight strokes. Evidence of arteriosclerosis is to be found as a rule in the retinal and peripheral circulation, with or without high blood-pressure. The differentiation of the presenile dementias may be difficult. These usually begin between 45 and 60. The commoner causes of dementia can readily be excluded. Encephalograms demonstrate some general dilatation of the cerebral ventricles with an excess of air over the anterior part of the hemispheres in Pick's disease, but more diffuse in Alzheimer's disease. Early psychomotor restlessness and jocularity and a family history of presenile dementia would favour Pick's disease as against Alzheimer's disease.

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CHAPTER XXII

THE NEUROSES

1. HYSTERIA

Definition: A neurosis characterized by mental dissociation leading in severe cases to multiple personality and amnesia, but more often to somatic symptoms such as convulsions, paralysis, and sensory disturbances in the absence of organic disease of the nervous system

Aetiology.

In hysteria the type of abnormal reaction exhibited by the patient is determined by the peculiar tendency of the hysterical personality to mental dissociation. In response to mental stress of a kind to be described later, the personality becomes split, certain psycho-physiological elements becoming separated from the conscious life of the individual. In the most severe cases the dissociated part of the mental life is so extensive that the patient may be regarded as suffering from multiple personality, since his body is at different times under the control of different personalities, which exhibit differences in temperament and which may or may not have access to each other's memories. A similar profound mental dissociation is responsible for the state known as hysterical fugue, in which the patient *disappears from home and wanders about*, having lost his sense of identity. During the period of fugue he has no access to the memories of his normal personality, and on recovery he may have no recollection of the events of his fugue. Such profound degrees of dissociation are, however, uncommon, and usually the splitting of the personality finds expression at the physiological level, part of the body being functionally cut off from the rest of the mental life, so that the patient is unable to move it or to feel with it, hysterical paralysis or anaesthesia resulting

The nature of the hysterical tendency to dissociation is little understood. It appears to be associated with a peculiarity of the emotional life of the hysterical patient. The poverty of the affective reactions of such individuals is well known—*la belle indifférence* of Janet—and Golla has shown that in spite of the violence of their somatic reactions the psycho-galvanic response to nocuous stimuli is *greatly depressed in hysterical patients* The underlying abnormality which finds expression in hysteria may well in many cases be inborn or at least may develop at an early age. Women suffer from hysteria much more frequently than men, and most hysterical individuals are relatively uneducated

The Mode of Production of Hysterical Symptoms.

The hysterical symptom is at the same time (1) a production of suggestion, (2) the expression of an idea in the patient's mind, and (3) a means to achieve a purpose.

(1) The precise nature of an hysterical symptom in a given case is usually, probably always, determined by suggestion. The suggestion frequently emanates from an organic disorder from which the patient actually suffers. Thus laryngitis may lead to aphonia, which is perpetuated as an hysterical symptom. Accidents of all kinds, for reasons which are discussed elsewhere, are apt to cause hysterical symptoms which perpetuate or exaggerate the disabilities produced by an injury. A doctor, nurse, or friend of the patient may unwittingly evoke an hysterical symptom by seeming to imply that a disability is to be expected. Finally, the symptom may be an imitation of an organic disorder in a person whom the patient – has seen and with whom for some reason he identifies himself.

(2) Suggestion operates through the patient's acceptance on irrational grounds of the idea that he is suffering from a certain symptom. It follows that the hysterical symptom is always the expression of an idea in the patient's mind. Thus hysterical aphonia expresses the idea 'I have lost my voice', hysterical paralysis the idea 'I cannot move my limb', and so on. This fact is of great diagnostic importance, for it is impossible that the patient's idea of a symptom should correspond with a similar symptom produced by organic disease, and the resulting discrepancy renders possible the diagnosis of the one from the other.

(3) The purposive character of the hysterical symptom is of great importance in connexion with treatment. The purpose served by the symptom can usually be expressed as the unconscious solution, however unsatisfactory, of a mental conflict. The patient finds himself in a situation in which a course of action which he desires to follow conflicts with his sense of duty or of self-respect. The development of the hysterical symptom unconsciously solves this conflict, though at the price of a neurotic disability. For example, a girl was compelled to give up her work to look after her invalid mother. She developed an hysterical paralysis of her right hand which prevented her from doing housework, and assistance had to be obtained to look after both her mother and herself. Her hysterical illness saved her from her unpleasant duty and at the same time preserved her self-respect, since she felt that no-one could blame her for being ill. At the same time she ceased to do any work at all, unconsciously revenged herself on her exacting parent, and became an object of sympathy to those with whom she came in contact. It is important to recognize

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that hysteria may fulfil other purposes than the solution of such a conflict, and that one symptom may achieve more than one object. The symptom frequently expresses a demand for sympathy, especially when the patient feels that he is neglected or insufficiently appreciated. Tyrannical parents and unfaithful spouses excite such a demand directly, while invalid parents and delicate brothers and sisters evoke it competitively. The hysterical symptom frequently possesses the further significance of being a symbol which expresses the patient's feelings. An example is the adoption of a crucifixion attitude in an hysterical fit.

The patient suffering from hysteria is thus primarily an individual confronted with a mental difficulty, often a conflict between two opposing impulses. While in this situation he receives a suggestion of ill health emanating either from an actual organic disease or from some outside source. He accepts this suggestion and manifests hysterical symptoms which provide a solution, albeit a pathological and unsatisfactory one, of his difficulty, and may also express in symbolic form his emotional reaction to his problem.

Symptoms.

(1) Amnesia and Multiple Personality.

Loss of memory and multiple personality are among the most striking symptoms of hysteria, and in outspoken forms are rare. The commonest example is the hysterical fugue, in which the patient disappears from home and wanders about, having lost his sense of identity. This state may last for hours, days, or even months, and on recovery the patient usually has no recollection of the events of his period of fugue. During the fugue he may be dazed and confused or he may be apparently normal and live as a normal individual, carrying on an occupation and exhibiting a mode of life different from his usual one. Hysterical amnesias and fugues are usually reactions to difficulties which render normal life intolerable. A wife has been known to react in this way to the infidelity of her husband and to adopt during her fugue the name of his mistress. A patient already in financial difficulties had a quantity of uninsured stock stolen from his motor. He drove for miles in a state of fugue, subsequently returning home exhausted and without any recollection of the events of the day, including the theft. In such a case the fugue and the amnesia constituted an escape from an unbearable situation which composed so large a part of the patient's life that he could only escape from it by suppression of a large field of consciousness. Amnesia may also occur in association with hysterical fits, the events of the convulsion being subsequently forgotten. Patients suffering from hysterical fugue may justly be regarded as

examples of multiple or dissociated personality, since they exhibit alternating phases of consciousness with mutually isolated memories. More complicated cases of multiple personality have been described in which more than two sub-personalities alternated or coexisted, some having access to the memories of the others. It is interesting to note that it has sometimes been possible to produce these dissociations of personality by hypnotic suggestion, and that the subject-matter of an hysterical amnesia can often be restored to consciousness under hypnosis.

By no means all cases of 'loss of memory' are hysterical in origin. Many other mental disorders lead to mental confusion or impairment of memory so that the patient may become lost and be unable to give an account of himself.

(2) *Convulsions.*

It is sometimes difficult to decide from the history whether convulsions are hysterical or epileptic, but the question is usually easily settled if the doctor is fortunate enough to witness a fit himself. The hysterical fit is a dramatic performance appropriately staged, hence it does not occur when the patient is alone or at least out of reach of an audience. Not infrequently the attack is directly precipitated by the emotional situation responsible for the neurosis. The onset is usually gradual and never of the fulminating suddenness of an epileptic fit. Whereas the epileptic falls to the ground with alarming violence and may injure himself, the hysteric subsides with some care, leaning, for example, against a wall or slipping slowly from a chair on to the ground. The epileptic fit follows a more or less stereotyped course, beginning sometimes with a cry and passing through a tonic phase, a phase of clonic, purposeless, jerking movements, and ending in post-convulsive coma of variable length, sometimes followed by automatism. In hysterical fits these phases do not occur. Crying out often occurs during the attack, but unlike the convulsive cry of the epileptic, which is merely an inarticulate phonation, consists of emotional reactions, e.g. laughing and crying, or the articulate utterance of words or sentences. The movements of the hysterical fit are not of a low order like the clonic movements of epilepsy, but are co-ordinated and purposive. The hysteric clutches at surrounding objects, struggles, and may attempt to fall out of bed or to tear off his clothes. Opisthotonos is common, and bizarre attitudes may be adopted. The tongue is not bitten in an hysterical convulsion, and incontinence of urine does not usually occur, but if the patient becomes aware that micturition is a characteristic of epileptic attacks, this symptom may be reproduced. In the convulsions of epilepsy consciousness is lost at the onset, so that the patient

during and immediately after the fit makes no response to external
stimuli. The hysteric when convulsed, though in an abnormal state
of consciousness, is not completely unconscious and can usually
be roused by sufficiently firm handling, whence the time-honoured
practice of administering a douche of cold water. The corneal reflex
accordingly is absent in an epileptic during a fit and during the phase
of post-convulsive coma. The corneal reflex is sometimes absent
in hysteria, but an attempt to elicit it during an hysterical fit often
evokes a violent contraction of the orbicularis oculi. The hysterical
fit, unlike the epileptic, has no well-defined termination but tails
away in sighs and groans and motor restlessness. After the attack
the hysterical patient, though shaken and exhausted, does not
usually exhibit the tendency to sleep which follows most epileptic
fits. The plantar reflexes are for a time extensor after a proportion
of epileptic fits. Flexor plantar responses after a fit do not exclude
epilepsy, but extensor responses in similar circumstances exclude
hysteria *as the cause of the fit*, provided there is no coexisting pyra-
midal lesion to which they are attributable.

The idea that there exists a condition intermediate between hys-
teria and epilepsy designated 'hystero-epilepsy' has now been dis-
carded, but it is important to remember that epilepsy and hysteria
may both occur in the same patient. The occurrence of an hysterical
fit after an epileptic convulsion is not uncommon, and when the
former follows an attack of petit mal it may obscure the com-
paratively insignificant manifestation of epilepsy, and unless careful
inquiry is made the true nature of the complaint may be missed.

(3) *Paralysis.*

Hysterical paralysis may affect any part of the body over which
there is normally voluntary control. Most commonly it involves
one limb or part of a limb, the movements at one joint being alone
affected. Less frequently more than one limb is affected, as in
hysterical hemiplegia, paraplegia, and diplegia. The paralysis may
be associated with flaccidity or rigidity, or there may be no gross
disturbance of muscle-tone. Hysterical paralysis of the face and
tongue is rare and is usually associated with spasm of the corre-
sponding muscles on the opposite side. *The diagnosis of hysterical
paralysis rests upon the following points:*

(i) *Anomalies of Distribution.* Since the paralysis corresponds
to the patient's idea, there are inevitably discrepancies between hys-
terical paralysis and that produced by organic lesions of the nervous
system. The distribution of the weakness is often anomalous. Thus in
hysterical hemiplegia there is no weakness of the face. Paralysis
limited to the movements at one joint is unknown in organic disease.

(ii) *Contraction of Antagonistic Muscles.* It is very common in hysterical paralysis to find that when the patient attempts to move the limb he contracts the antagonistic muscles as well as the prime movers Thus extension of the elbow is associated with active contraction of the biceps, flexion of the knee with contraction of the quadriceps Such antagonistic contractions can easily be detected by the observer if he places a finger upon the biceps-tendon and patella respectively Such a disorder of movement expresses mental conflict at the physiological level in a simultaneous contraction of the muscles which would carry out a movement and of those which would prevent it. Antagonistic contraction is absent when the paresis is so great that the prime movers hardly contract at all.

(iii) *Muscular wasting, muscular contractures, and the reaction of degeneration* are absent except in cases of long standing, in which these phenomena may supervene upon the prolonged muscular inactivity

(iv) *The Reflexes.* The tendon-reflexes in hysteria depend upon a number of variable factors. There is often a symmetrical and moderate exaggeration. Extreme rigidity may make them difficult to elicit. Moderate unilateral rigidity may render them exaggerated on the affected side, but if adequate muscular relaxation can be obtained they are never asymmetrical and never diminished. The same is true of the abdominal reflexes, and the plantar reflexes are flexor unless the patient has learned the pathological significance of an extensor plantar response. True ankle clonus does not occur, though a few clonic jerks may be evoked if the lower limb is incompletely relaxed.

Gait.

Hysterical disorders of gait may be associated with hysterical paralysis of one or both lower limbs, and are not uncommonly a perpetuation of the normal instability which occurs on first getting out of bed after an illness. An hysterical gait is usually easily recognized on account of its bizarre character and its dissimilarity from any disorder of gait produced by organic disease. In hysterical hemiplegia the affected lower limb is ostentatiously dragged along the ground and not circumducted, as in hemiplegia due to a pyramidal lesion. When the disorder involves both lower limbs, stiffness and ataxia are present to a varying extent. Not infrequently a patient who, while lying in bed, exhibits normal power and co-ordination, walks with the greatest difficulty, clinging to the bed and the furniture. There is often a tendency to fall, especially when other patients are present, but the fall does not lead to injury. In severe cases there is a complete astasia-abasia, and two persons may have

difficulty in supporting the patient, for whereas a patient with organic disease leading to difficulty in walking does his best to support himself, the unconscious efforts of the hysterical patient are directed to falling

Rigidity.

Hysterical rigidity may be localized to a paralysed limb, or generalized, as in hysterical trance. It is distinguished from all forms of rigidity due to organic disease by the fact that it increases in proportion to the effort made by the observer to move the rigid part, whereas in organic disease of the nervous system the rigidity is a definite quantum which can be overcome by the exercise of a slightly greater force. Moreover, in hysteria a successful attempt to break down the rigidity almost always leads to an intense emotional reaction in the patient.

Involuntary Movements.

Tremor is a common hysterical involuntary movement. It may be fine or coarse, generalized or localized. A coarse tremor is often associated with hysterical paralysis, being intensified when the patient attempts to move the paralysed limb. It is increased when attention is directed to it, and may be absent in movements carried out when the attention is distracted. Hysterical involuntary movements may simulate chorea, though not with sufficient accuracy to deceive the skilled observer. In such cases movements do not usually involve the face.

Sensory Symptoms.

Hysterical sensory impairment is common. It is most often confined to a limb which is the site of other hysterical symptoms, for example, paralysis. It may affect some forms of sensibility only, especially appreciation of light touch and cutaneous pain, or all forms may be lost. When cutaneous sensibility is lost over the peripheral segments of the limb, the anaesthetic area is demarcated *from the area of normal sensibility by a sharp upper border* which encircles the limb and usually coincides with a joint. Sensation is not uncommonly lost over half of the body, and in such cases there may be loss of smell and taste on the same side. Anaesthesia of the whole body is less frequent. Anaesthesia of the cornea, palate, and pharynx, with loss of the corresponding reflexes, is an unexplained *symptom of hysteria which may be present without other sensory* disturbances.

Hysterical sensory loss is distinguished from that due to organic disease of the nervous system by its failure to correspond with the distribution of the loss resulting from lesions of the sensory tracts,

spinal segments, or peripheral nerves. Anaesthesia of the 'glove and stocking' distribution may simulate that found in polyneuritis and in subacute combined degeneration, but in these disorders the transition from impaired to normal sensibility is always gradual. Hysterical patients often exhibit striking discrepancies in their sensory symptoms which are incompatible with an organic origin. Thus coordination may be perfect in spite of complete loss of postural sensibility and appreciation of passive movement in a limb. Or a patient with hysterical hemianaesthesia may state that he is unable to feel a vibrating tuning-fork placed over the affected half of the sternum, although the bone conducts the stimulus perfectly to the opposite side. In hysterical persons sensory loss can readily be, and perhaps always is, produced by suggestion.

Deafness. There is little difficulty in detecting hysterical deafness when examination reveals that the ears and vestibular reactions are normal, but the diagnosis is more difficult when hysterical deafness is superimposed upon a reduction of hearing due to organic disease of the ears. Hysterical deafness may disappear during sleep, so that the patient can be aroused by sounds, and the blinking reflex on auditory stimulation may be retained by the hysterically deaf. When Bárány's noise-box is used, a patient suffering from hysterical deafness will raise his voice, but this does not occur when deafness is due to disease of the ear. Hysterical vertigo is rare.

Pain. There has been some discussion as to whether hysterical pain is qualitatively the same as the pain produced by organic disease, and this has been denied on the ground that the hysterical patient, though complaining of severe pain, usually exhibits none of the physical reactions which are associated with pain of organic origin and presents an appearance which belies his allegations of intense suffering. Nevertheless, since pain is essentially a psychical state, there seems no reason why it should not sometimes be psychogenic, and it does not follow that pain thus induced would necessarily be associated with the physiological concomitants of pain excited at lower levels of the nervous system. Hysterical pain is especially common in the head and spine. The recognition of its nature depends upon the absence of symptoms of organic disease sufficient to explain it, its failure to respond to analgesic drugs, often including morphine, and to alcoholic injection of the nerves innervating the affected region, and upon the mental state of the patient, who is usually distressed and agitated by the pain to an abnormal degree.

Ocular Symptoms.

Hysterical blindness may be unilateral or bilateral and may be complete or may consist merely of a reduction of visual acuity.

Bilateral blindness is not uncommonly a perpetuation of the transitory visual impairment associated with syncope or with head injury. Unilateral blindness may be associated with hysterical hemianaesthesia on the same side. In hysterical blindness the optic disks and the pupillary reactions to light are normal, and it may be possible to evoke blinking by a sudden feint with the hand towards the eyes. Moreover, the blind hysteric may avoid obstacles in his path. There are a number of tests for the detection of unilateral hysterical blindness. Diplopia may be produced by covering one eye with an appropriate prism. One eye may be covered with a red, and the other with a green glass, the patient being then asked to read a word-test of alternate red and green letters. Since one colour is invisible to each eye, if all the letters are read the patient must be using both eyes. Visual field defects are common in hysteria and are usually the result of suggestion at the time of examination. The commonest type *is* a concentric defect of the field which takes the form of a spiral with the field progressively diminishing with each circuit of the test object.

Disturbances of the ocular movements include spasm of convergence, which is almost always hysterical and may be associated with spasm of accommodation. Defects and dissociation of conjugate ocular movements in the lateral and vertical planes may be produced by spasm of the ocular muscles, and a coarse nystagmus may occur. Hysterical ptosis is the result of spasm of the palpebral fibres of the orbicularis oculi, and when the lid is passively raised this spasm can be felt to increase. Blepharospasm is similarly produced.

Symptoms referred to the Alimentary Canal.

Hysterical dysphagia may occur, but is rare. Air-swallowing is common and is usually begun by straining to bring up wind. It may lead to extreme gastric distension. Globus hystericus, described as a sensation of constriction or a lump in the throat, is probably also usually the result of air-swallowing and is a referred sensation produced by the presence of air in the lower part of the oesophagus.

Hysterical vomiting when mild may lead to no loss of weight, when severe may cause marked acidosis and emaciation. It is usually symbolic of an intense aversion from some task or situation, of which the patient is literally, *as well as* metaphorically, *sick*.

Hysterical anorexia— '*anorexia nervosa*' —may arise as a primary hysterical reaction to the patient's difficulties, or may be secondary to other hysterical symptoms referred to the alimentary canal, and which the patient believes are exacerbated by taking food. It occurs in adolescent girls and young women and may lead to extreme emaciation and to amenorrhoea.

Hysterical diarrhoea and constipation may occur, and it is probable that many of the abdominal and pelvic symptoms usually attributed to visceroptosis are in part or entirely hysterical.

Cardiac Symptoms

Tachycardia and palpitation play a prominent part in the symptoms of neurotic anxiety. In hysteria, however, such symptoms may occur in a patient who is outwardly placid. The recognition of their nature is of great importance, since many sufferers from these symptoms are confined to bed for long periods with a mistaken and harmful diagnosis of organic heart disease or exophthalmic goitre.

Respiratory Symptoms.

Respiratory tics have already been described.   Hysterical hyperpnoea is not uncommon and usually follows a fright. I have known it produced by suggestion in a patient with congenital dextrocardia. The excessive ventilation of the lungs may lead to tetany. The hysterical nature of the symptom can usually be detected by the fact that the hyperpnoea disappears or is much diminished when the patient is engaged in conversation, whereas talking increases the dyspnoea due to organic disease.

Urinary Symptoms.

Nocturnal enuresis in childhood is the perpetuation of, or a reversion to, the infantile lack of control over the bladder. Its motive is frequently a desire to attract attention, and the symptom tends to be maintained by punishment and by suggestions emanating from a household in which the lapse comes to be expected. Pathological polyuria and organic causes of enuresis, especially spina bifida occulta, must be excluded. Hysterical retention of urine usually occurs in young girls and by force of suggestion may become epidemic in a girls' school.

Sexual Symptoms.

Hysterical impotence is usually the expression of anxiety, which, being associated with excitation of the sympathetic nervous system, is inhibitory to sexual activity, with the exception of contraction of the vesiculae seminales, to which the sympathetic sends motor fibres. The combined inhibitory and motor influence of the sympathetic upon sexual activity explains the frequent association of impotence with premature ejaculation. The anxiety which leads to impotence may be due to a variety of causes, including general feelings of physical inferiority, fears of the ill effects of masturbation, and a sense of moral guilt evoked by an illicit sexual union, or even by the

marital sexual relationship. Care must be taken to exclude both diseases of the nervous system, especially tabes, and conditions of general ill health which may cause impotence (see p. 822).

Vaginismus, which is often associated with, and attributed by the patient to, dyspareunia, is usually the expression either of the patient's lack of love for her husband or of a refusal to accept the responsibilities of married life, especially a fear of pregnancy.

The Skin.

'Dermatitis artefacta' is the term applied to cutaneous lesions voluntarily produced by an hysterical patient, either by scratching or rubbing, or by the use of external agents, including corrosives. These are usually easily recognized by their appearance and by the fact that they quickly heal when covered by an occlusive dressing. There seems little doubt that cutaneous lesions of an erythematous, urticarial, or bullous nature may arise spontaneously in hysteria, and similar lesions can be produced in some subjects by hypnotic suggestion. Pruritus is frequently an hysterical symptom. Cyanosis and oedema may occur in a limb which is the site of hysterical paralysis.

The Spine.

The spine may be the site of hysterical pain and tenderness, and occasionally remarkable deformities occur in hysteria, sometimes leading to a shortening of several inches in the vertebral column.

Pyrexia.

Probably in most cases of apparent pyrexia occurring in hysteria, the thermometer is manipulated by the patient. This source of error can readily be detected by adequate supervision when the temperature is taken. In certain cases, however, it appears that an actual rise of body temperature may occur as an hysterical symptom.

Speech.

Hysterical speech disturbances—mutism and aphonia—are described elsewhere.

Diagnosis.

The diagnosis of individual hysterical symptoms has already been considered. In general it may be said that the diagnosis of hysteria depends upon the presence of positive signs of hysteria already described in connexion with individual symptoms, and the absence of signs of organic disease. It is essential in every case, therefore, that a thorough examination should be made both of the nervous system and of other systems to which symptoms may be referred.

The organic nervous disease most likely to be confused with hysteria is disseminated sclerosis, on account of the transitory occurrence in the early stages of this disorder of weakness and sensory disturbances. Careful examination of a patient with disseminated sclerosis, however will always reveal signs of organic disease of the nervous system, the commonest of which are pallor of the optic disks, nystagmus, diminution or absence of the abdominal reflexes, and extensor plantar responses.

Prognosis.

The prognosis as to recovery from an individual symptom of hysteria is good in most cases, though relapses are frequent, unless the patient can be induced to carry out a considerable psychological readjustment. Chronic cases are not uncommon in which a single symptom persists for years, often because it is the patient's reaction to a domestic situation which also persists unchanged. Victims of chronic hysteria are usually either persons of low intelligence or those in whom the expectation of compensation for an injury or the receipt of a pension puts a premium upon the persistence of their disability.

Treatment.

General Considerations.

Since, as we have seen, an hysterical symptom is a neurotic solution of a mental conflict, symptomatic treatment alone is inadequate. It is essential that the cause of the conflict should be discovered and that the patient should be induced to deal with it in a manner which does not involve resort to a neurosis. Analytical psychological methods, however, are often rendered difficult by lack of intelligence or by resistance in the patient, and in severely dissociated individuals with amnesia, hypnosis may be necessary to recover forgotten episodes. When the cause of the symptom has been discovered and dealt with, treatment may also be directed towards the relief of the symptom itself. A careful physical examination must be made in order that the patient may be assured that no organic cause for the disability exists, but that it is due to a faulty mental habit. The patient must be convinced that he can overcome the disability, but care should be taken to avoid the suggestion that this requires a great effort of will, since this attitude implies that the achievement is difficult. In some cases recovery is best effected by a gradual process of persuasion and re-education extending over a considerable time. Some, however, prefer to attempt to remove the symptom at one sitting. This method requires great tact and patience on the part of the physician and is not without risk, since the failure of a protracted attempt to cure will only reinforce the patient's belief in the

intractable nature of his disorder. The removal of a symptom by hypnotic suggestion is usually undesirable in adult patients, since it tends to strengthen the abnormal suggestibility which is an undesirable characteristic of the hysteric. This method, however, is admissible in dealing with children, in whose education suggestion plays a legitimate part

Treatment of Individual Symptoms

Convulsions. An hysterical convulsion can usually be quickly terminated by firm handling, especially if the patient is isolated from a sympathetic audience.

Paralysis and Rigidity These symptoms are commonly associated, and, since they depend in part upon involuntary muscular contraction, this should be explained to the patient, who should first be directed to relax the muscles of the affected region and should be told that when the muscles are relaxed movement will be easy. Faradism may be employed to demonstrate that the muscles are still capable of contraction, the patient then being made to imitate the movements excited electrically

Abasia. Abasia is a symptom which lends itself to cure at a single treatment. The patient is first encouraged to walk with adequate support, the doctor walking on one side. The support is gradually diminished until the patient can be told that he is now walking alone, and finally he should be induced to run.

Enuresis Before regarding enuresis in childhood as a neurosis it is necessary to exclude irritative lesions of the urinary tract, polyuria, and organic lesions which impair sphincter control, especially spina bifida occulta. An attempt should be made to ascertain the cause of the symptom, which is frequently a desire to attract attention. Both the parents and the patient should be encouraged to expect a cure, and neither blame nor punishment for lapses should be permitted. Tincture of belladonna in full doses may be used to depress reflex evacuation of the bladder until the habit of continence is established. Hypnotic suggestion will often rapidly bring about a cure in hitherto intractable cases.

Vomiting. The psychological cause of the vomiting must first be ascertained and discussed with the patient, who must be reassured that no organic cause for it exists. Special diets, alkalies, and nutrient enemas will often have been employed in treatment. These and the apparatus connected with them should all be removed from the room. An ordinary light meal should then be obtained and the patient persuaded to consume it with the assurance that no vomiting will follow. An attempt should always be made to cure hysterical vomiting at one sitting, a cure once effected being permanent.

Anorexia Nervosa. The patient should be isolated from relatives
and friends and the cause of the anorexia ascertained. It is often
necessary to explain that the symptoms which the patient attributes
to taking food are really the result of taking too little. A beginning
should be made with frequent small feeds, and no effort should be
spared to make the diet attractive. An acid mixture will often relieve
flatulence and improve appetite, and it is usually necessary to treat
constipation

2. ANXIETY NEUROSIS

Definition: Neurotic anxiety may be defined as anxiety which
occurs in an individual who is otherwise mentally normal and which
is either directed towards some object or situation which does not
normally excite it or which is experienced as an undirected emotional
state, the cause of which the victim is unable to explain. Psycho-
logical investigations have shown that this apparently misdirected
or undirected anxiety has always arisen in circumstances which
afford an intelligible explanation of it though the patient is largely
or entirely unconscious of it For the psychological analysis of
anxiety the reader is referred to text-books of psychological medicine.

Symptoms.

Mental Symptoms

The primary mental symptom of anxiety neurosis, as we have
seen, is anxiety, which may be directed against specific external
objects or situations in the form of phobias, or may be a more
diffuse mental state with no cause apparent to consciousness. The
patient may be subject to paroxysmal exacerbations of anxiety,
known as anxiety attacks, in which an overwhelming sense of anxiety
dominates consciousness and is associated with the somatic con-
comitants of anxiety in an intense form. Other mental symptoms
which are often associated with anxiety and which are the outcome
of the patient's preoccupation with his neurosis include irritability,
depression, lack of concentration, and insomnia, and anxiety may
find expression during sleep in terrifying dreams and nightmares.

Physical Symptoms.

Anxiety is attended by an enhanced activity of the sympathetic
nervous system, and many of its physiological manifestations are
directly or indirectly the result of this. The patient often complains
of palpitation, weakness and fatiguability, dyspnoea, giddiness, a
sensation of falling, a sense of pressure at the vertex, loss of appetite,
epigastric discomfort, flatulence, constipation, diarrhoea, frequency
of micturition, and seminal emissions. On physical examination

the pupils are often dilated, the pulse rapid, the extremities cold, cyanosed, sweating, and tremulous. The tendon reflexes are exaggerated. Slight enlargement of the thyroid is not uncommon. The blood-pressure may be raised but is frequently somewhat subnormal.

Diagnosis.

The anxiety attack must be distinguished from other paroxysmal disorders, especially from epilepsy, syncope, vaso-vagal attacks, and aural vertigo. There is usually little difficulty in making the correct diagnosis in view of the prominence of anxiety, the absence of loss of consciousness and true vertigo, and the presence of symptoms of overaction of the sympathetic nervous system, especially tachycardia. Anxiety neurosis must be distinguished from minor impairment of mental function resulting from organic disease of the brain, especially cerebral syphilis and arteriosclerosis, encephalitis lethargica, and intracranial tumour. Anxiety, associated with impairment of memory and capacity for concentration, and irritability, may be a symptom of these and other organic nervous disorders. A carefully taken history and systematic examination of the nervous system, however, will enable the organic origin of the condition to be diagnosed, and this may be confirmed by appropriate serological or other examinations. Anxiety neurosis must also be distinguished from more profound mental disorders, of which anxiety may be a symptom, especially from agitated depression and certain cases of schizophrenia. In the former the anxiety is usually explained by the patient as a reaction to terrifying circumstances which can be shown to be delusions, and when anxiety is a prominent symptom of schizophrenia, it is usually quite evident that the mental disorganization is much more serious than occurs in a neurosis.

Prognosis.

The prognosis of anxiety neurosis is on the whole good. The disorder is not in itself fatal and neurotic patients rarely commit suicide. When the neurosis is of recent origin and a reaction to a well-defined source of fear, a cure can often rapidly be effected. Those patients in whom anxiety is an habitual reaction of long standing, dating from childhood, may require prolonged treatment, but, provided they are co-operative and intelligent, they also may be much benefited and in many cases cured. Relapses, however, are not uncommon.

Treatment.

The treatment of anxiety neurosis must always be psychological. Physical measures, however, have their place, especially in the treatment of the more severe cases. In such cases the patient must be isolated from his usual environment, in a nursing-home or hospital.

Merely to send him away from home without arranging psychological treatment at the same time is useless, since he carries his mental maladjustment with him. Adequate rest must be ensured, and many patients benefit from complete rest in bed for a few weeks, sedative drugs, such as bromide and phenobarbital, being given, and a sufficient dose of a soporific to ensure sleep. The patient should be regularly massaged while in bed, and taught to practise muscular relaxation, and, later, graduated physical exercises may be employed to promote a sense of well-being and to prepare him for a return to work.

Psychological treatment is directed to discovering the cause of the patient's anxiety, bringing him to a realization of its relationship to his symptoms, and inducing him to alter his emotional attitude to the source of his fears. Adults who complain of anxiety neurosis of recent onset are usually suffering from the focal type of anxiety reaction. In such cases the cause of the anxiety can usually rapidly be ascertained by judicious questioning, which may follow the ordinary lines of history-taking, the patient's psychological reactions to his parents, brothers, and sisters, married life, and occupation being ascertained in turn. Direct questions may be asked concerning possible causes of worry, especially as to fears of specific diseases. When fear of ill health is the source of anxiety a thorough and careful physical examination must be made, and this will often enable the doctor to explain to the patient that his fears are groundless. Other sources of anxiety may be less easily dispelled, but when once the cause is discovered much can be done to help the patient to adopt a more healthy attitude to his difficulties. Anxiety attacks arising in certain situations are often due to a fear of the recurrence of an attack of illness which the patient has once suffered in similar circumstances and a cure often rapidly follows the patient's appreciation of their true nature. Anxiety reactions of long standing usually require prolonged psychological investigation, either psychoanalysis on the lines laid down by Freud, or some modification thereof, being necessary, free association, word association, the analysis of dreams, and similar methods being used to reveal to the patient his unconscious mental processes.

3 NEURASTHENIA

Definition: A neurosis characterized by marked mental and physical fatiguability.

Aetiology.

On psycho-pathological grounds there is perhaps little justification for distinguishing a separate form of neurosis by the title 'neuras-

thenia'. Nevertheless, for clinical purposes the term is a convenient one. Neurasthenia in the sense defined is rare and its aetiology is somewhat obscure. It is probable that in most cases it is an hysterical symptom which fulfils the purpose of sheltering the patient from the difficulties involved in an active life. The excessive fatiguability may also be a by-product of the absorption of mental energy in repression or conflict.

Symptoms.

In the mental sphere the patient's fatiguability finds expression in inability to concentrate and some impairment of memory, and is often associated with slight depression. Physically there is an inability to undertake even moderate exertion without excessive fatigue, and other somatic symptoms include fatiguability of the eyes in reading, palpitation, and breathlessness on exertion. The symptoms are usually at their worst in the morning and tend to improve during the day. In severe cases the patient is unable to carry on an occupation.

The neurasthenic patient is not uncommonly physically under-developed and possesses a sallow complexion, flat chest, and a long narrow abdomen. The muscles are hypotonic and the extremities are usually cold and somewhat cyanosed. The pulse is unstable and often rapid and the blood-pressure is low.

Diagnosis.

Neurasthenia must be distinguished from cyclothymic depression (the depressive phase of manic-depressive psychosis). This form of depression, being associated with mental retardation, frequently leads to a complaint of excessive fatiguability. In cyclothymia, however, the depression is more profound than in neurasthenia. The disorder exhibits a marked periodicity with a tendency to spontaneous recovery in a few weeks or months and often occurs in short, thick-set individuals of a physical type quite different from that usually associated with neurasthenia. Organic disease of the nervous system, especially encephalitis lethargica and neurosyphilis, may lead to mental symptoms resembling neurasthenia, but these conditions can be distinguished by the history and presence of characteristic physical signs. Myasthenia gravis, in common with neurasthenia, leads to excessive fatiguability. This symptom in myasthenia, however, increases in severity towards the end of the day and leads to muscular paresis, of which ptosis, diplopia, and dysphagia are the commonest manifestations. It is necessary also to distinguish neurasthenia from organic diseases in which fatigue results from toxaemia, especially exophthalmic goitre, and pulmonary tuberculosis. Careful examination, however, will reveal the signs of these disorders

Prognosis.

The prognosis of neurasthenia is on the whole less satisfactory than that of most other neuroses, perhaps because there is often an underlying physical inadequacy.

Treatment.

Psychological treatment should be carried out on the same lines as for anxiety neurosis and hysteria. Physical treatment is of special importance. Massage and graduated exercises should be employed to strengthen the muscles and increase the patient's tolerance for fatigue. When the weight is subnormal an attempt should be made to increase it by means of a suitable diet, and sedatives or tonics should be used as seems appropriate in individual cases.

4. OBSESSIVE-COMPULSIVE NEUROSIS

Definition: The obsessive-compulsive neurosis is characterized by the persistent obtrusion into consciousness of ideas or emotional states—obsessions, or impulses to action—compulsions, independently of the patient's will, without a cause which is evident to his consciousness and in spite of his recognition of their irrational character.

Aetiology.

The obsessive-compulsive neurosis is the manifestation of a specific psychological constitution, often hereditary and compatible with great intellectual capacity and physical energy. Though no doubt the symptoms can be partially explained in psychological terms as unconscious reactions of the patient to his experiences, their peculiar character is determined by his innate psycho-physiological constitution. Psychologically the cardinal features of this are (1) a sense of bondage to the past, (2) a tendency to sado-masochism, (3) a primitive affective life in which guilt demands expiatory rituals, and (4) a conspicuous tendency for the neurosis to find expression in bodily movements. The psychogenesis of compulsive symptoms is most obvious in the ties of childhood which are often a reaction to psychological difficulties in the home or school and possess features of hysteria as well as of the compulsive neurosis. The fact that sufferers from encephalitis lethargica are occasionally subject to both obsessional ideas and compulsive movements, ties, indicates the importance of the physiological factor in the constitution.

Many obsessionals, such as John Bunyan and Dr. Johnson, have been men of eminence in literature or affairs.

Symptoms.

The simplest symptoms of the obsessive compulsive neurosis are the tics of childhood. Tics are repetitive involuntary movements which may originate as automatic or voluntary reactions to a local stimulus or external situation and are perpetuated as compulsive symptoms. Thus blepharitis or conjunctivitis may initiate a blinking tic which persists after the inflammation has subsided. Tics frequently involve the facial muscles as in blinking or movements of the eyes or mouth. Rotation of the head is a common tic and spasmodic torticollis is sometimes a symptom of a compulsive neurosis. Respiratory tics include sneezing, coughing, and hiccup and in some complicated tics the limbs and the whole body may be involved. Dr Johnson's elaborate gesticulations were of this kind. The sufferer from a tic experiences a conscious compulsion to carry out the movement and increasing discomfort until he yields to it though he can give no explanation of this insistent need.

A somewhat more complex type of compulsive symptom is a compulsion to carry out a more complex set of movements animated by a strongly felt but unexplained emotional state. Compulsive washing is a good example of this. A constant fear of contamination leads to frequent washing and in a severe case the unfortunate patient may have little time for anything else. Similarly obsessive doubts may lead the bank-clerk to go back repeatedly to assure himself that he has locked the strong-room or the housewife that she has turned off the gas.

At the ideational level obsessions may consist of fears. *Syphilophobia* is a not uncommon example. In this case the patient is unable to rid himself of a groundless fear that he has contracted syphilis or that an infection which has been cured is still persisting. Obsessional fear may centre upon other forms of disease, such as *cancer*, or may be directed against external objects, such as *knives*, with which the patient may fear that he will attack some one or commit suicide. Sexual obsessions are common and some patients continually repeat to themselves obscene expressions or fear that they will utter them in public. Finally, obsessions of sin and the dangers of damnation may, as in Johnson's case, haunt the victim throughout a long life. Obsessions may lead to profound depression and sometimes suicide.

Diagnosis.

The compulsive character of the symptoms in obsessionals is so distinctive that the diagnosis is usually easy. The involuntary movements, however, must be distinguished from those of organic origin,

especially chorea. Distinguishing features are the repetitive character of the simpler forms of tic and the complex and elaborate nature of the more highly organized involuntary movements.

Prognosis.

Most children who suffer from tics recover though a few continue to twitch throughout their lives. The more serious obsessional symptoms, especially compulsive ideas and elaborate compulsions such as washing, are difficult to treat, perhaps because of their constitutional basis. In the milder cases many lose their obsessions: some of those most severely affected end in psychosis or suicide.

Treatment.

Prolonged rest, isolation in a suitable home and psychotherapy are essential in severe cases. As already mentioned tics in children are often reactions to difficulties in the home or at school and have often been injudiciously treated by the parents. The tic will usually disappear if no allusion is ever made to it. If this fails the child should be sent away from home for a few weeks. Muscular relaxation and re-educational exercises are helpful.

5. TRAUMATIC NEUROSIS

Aetiology.

The development of a neurosis as a sequel to an injury is frequently of considerable medico-legal importance. It is convenient to distinguish two groups of patients in which this may occur, according to whether the injury does or does not entail the possible receipt of compensation. An injury may precipitate the development of an hysterical symptom when there is no question of compensation. In such cases the injury merely suggests the disability, and the cause of the neurosis must be sought elsewhere. In the other group the neurosis arises out of the situation in which the patient finds himself as a result of the injury. Traumatic neuroses are common sequels of industrial accidents and are somewhat less frequent after accidents of other types. A person who sustains an accident in the course of his occupation and is thereby disabled is commonly put upon half pay for an indefinite period, until either he is well enough to return to work or his claim for compensation is finally settled, frequently after litigation. It is easy to see how adversely this unsatisfactory system reacts upon the mental health of the injured individual. Not only the disability resulting from his accident but also the prolonged period of inactivity tend to render him unfit for work, and during this time he has nothing to do but brood over his injury and worry over his risks of unemployment. According to his temperament he

is liable to react either by a state of anxiety, which carries with it numerous disabling bodily symptoms, or by an hysterical symptom which perpetuates his disability and appears to enhance his claim to compensation. A similar mental state is liable to develop in the case of a soldier who receives a pension for a temporary disability.

Symptoms.

The symptoms of anxiety neurosis and of hysteria following an injury do not differ from those of the same disorders produced in other ways.

Diagnosis.

A careful physical examination is necessary in order to differentiate organic symptoms due to the injury from superimposed neurotic symptoms. This is especially important in the case of head injuries, since the symptoms of cerebral contusion are not uncommonly mistakenly regarded as neurotic. The diagnosis of hysteria from malingering may be extremely difficult, the distinction resting upon whether or not the symptoms are consciously adopted for the purpose of obtaining compensation. Since most persons regard malingering as immoral, the desire to malinger frequently gives rise to a mental conflict which solves itself by an hysterical symptom. Malingering is, therefore, rare.

Prognosis.

The prognosis of traumatic neurosis is notoriously unsatisfactory, and little or no improvement can be expected until a pending claim to compensation is finally settled, and by no means always then.

Treatment.

The treatment is that of anxiety neurosis or of hysteria, and every effort should be made to expedite a settlement of the patient's claim. Traumatic neurosis can often be prevented when the injury is mild by reassuring the patient in the early stages and by arranging with the employer for his early return to light work. Much misery and disability could be avoided if a system could be devised by which claims to compensation could be rapidly settled on the advice of *a medical referee, instead of, as now, being submitted* to long-postponed litigation and the decision of a judge on the basis of conflicting medical evidence.

6. OCCUPATIONAL NEUROSIS

Synonyms: Craft palsy; occupational cramp.

Definition: A functional nervous disorder prone to afflict those whose occupation entails the persistent use of finely co-ordinated

movements, especially of the hand, and characterized by a progressive occupational disability, due to spasm of the muscles employed, which are often the site of pain and sometimes of tremor.

Aetiology.

Occupational neurosis has been attributed to fatigue of cortical ganglion cells and has also been regarded as a disorder of the basal ganglia. It seems more probable, however, that it is a neurosis. We know of no organic disorder in which the movements are impaired when they take part in one co-ordinated act but remain unaffected in others. The muscular spasm evoked by an attempt to carry out the act involves both prime movers and their antagonists, and thus resembles the disorder of function which occurs in hysterical paralysis. The disability in occupational neurosis may be influenced by external factors in a manner which seems inexplicable if it is due to an organic disorder. For example, a solicitor who suffered from severe writers' cramp was almost totally unable to write when sitting, but could write quite well when standing. Occupational neurosis, moreover, may be associated with typical hysterical symptoms, and investigation may elicit an adequate psychological cause. Thus a woman who developed writers' cramp after an unhappy marriage suffered also from vaginismus. Finally, in some cases, occupational neurosis is curable by psychotherapy. It thus presents many points of resemblance to stammering, another functional disorder of finely co-ordinated movements; indeed, occupational neurosis may be described as a manual stammer. It must be admitted, however, that sufferers from occupational neurosis may possess a physiological predisposition which determines the character of their neurosis, as, for example, left-handedness appears to predispose to stammering.

Fatigue and the effort to carry out accurate work against time are important precipitating factors, and since in most cases the sufferer's livelihood depends upon his speed and accuracy, an impairment of his efficiency evokes anxiety, which probably plays a part in the psychogenesis of the disorder. Numerous occupational neuroses have been described, writers', telegraphists', gold-beaters', and piano-players' cramps being the most familiar, but there is probably no occupation involving the repetition of fine movements which is immune. Both sexes are affected, but males more often than females.

Symptoms.

The symptoms of writers' cramp will alone be described, since the disorder is essentially the same in other occupations. The onset of symptoms is gradual, and the disorder shows itself at first only when

the patient is fatigued, when a difficulty in controlling the pen leads to inaccurate writing. When the condition is well developed the attempt to write evokes a spasm of the muscles concerned in holding and moving the pen, and this may spread to the whole of the upper limb The whole limb may thus become rigid, so that the act is brought to an abrupt stop. More usually the attempt to write leads to jerky and inco-ordinate movements of the fingers, so that the writing is completely illegible The pen may be driven into the paper. In some cases a tremor of the hand develops. No two patients present precisely the same disorder of function An attempt is often made to circumvent the disability by various tricks and unusual methods of holding the pen. Extension of the muscular spasm beyond the upper limb is rare. Sensory symptoms are common and are the result of the muscular spasm, the patient complaining of a sense of fatigue or an aching pain in the muscles, not only of the upper limb but sometimes also of the neck. Muscular wasting, sensory loss, and reflex changes are absent In the early stages the disability is limited to the single act in which it originates. Later it may extend to other acts which are carried out by the same hand. Thus the woman already mentioned, after developing writers' cramp, learned to use a typewriter. Her disability then extended to typing and finally to the use of a paint-brush in water-colour sketching. The sufferer from writers' cramp who learns to write with the left hand may develop the same disorder in this.

Diagnosis.

Occupational neurosis must be distinguished from organic disorders of the nervous system which may lead to a difficulty in carrying out fine movements. A careful history and physical examination usually render the diagnosis easy, since in such cases signs of organic disease are always present and the disability usually involves all finely co-ordinated acts to an equal extent from the beginning.

Prognosis.

The prognosis of occupational neurosis is usually bad, since in many cases the disability is progressive, though recovery may occur and some patients may be able to continue their occupation in spite of their disorder.

Treatment.

Prolonged rest from the occupation is essential, and the period of rest should be occupied by psychological investigation and appropriate psychological treatment. The way in which muscular spasm interferes with the act should be explained to the patient, and he

should be taught muscular relaxation under skilled supervision.
This should later be combined with re-educational exercises for the
affected limb, and return to work should be gradual, fatigue being
avoided. The patient's general health should be improved by means
of Swedish remedial exercises and other appropriate measures.

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